

BMJ Open

Burden of Poor Oral Health in Older Age: Results from a Population-based Study of Older British Men

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2015-009476
Article Type:	Research
Date Submitted by the Author:	22-Jul-2015
Complete List of Authors:	Ramsay, Sheena; UCL, Primary Care & Population Health Whincup, Peter; St Georges, University of London, Population Health Research Institute Watt, Richard; UCL, Epidemiology and Public Health Tsakos, Georgios; UCL, Epidemiology and Public Health Papacosta, Olia; UCL, Department of Primary Care and Population Health Lennon, Lucy; UCL, Department of Primary Care and Population Health Wannamethee, Goya; UCL, Department of Primary Care and Population Health
Primary Subject Heading:	Dentistry and oral medicine
Secondary Subject Heading:	Epidemiology, Public health, Geriatric medicine
Keywords:	EPIDEMIOLOGY, ORAL MEDICINE, PUBLIC HEALTH, GERIATRIC MEDICINE

SCHOLARONE™
Manuscripts

1
2 **Burden of Poor Oral Health in Older Age: Results from a Population-based Study of Older British**
3 **Men**
4

5 SE Ramsay,¹ PH Whincup,² RG Watt,³ G Tsakos,³ AO Papacosta,¹ LT Lennon,¹ SG Wannamethee¹

6
7 ¹Department of Primary Care & Population Health, UCL, London, UK

8 ²Population Health Research Institute, St George's University of London, London, UK

9 ³Department of Epidemiology & Public Health, UCL, London, UK
10

11
12 Corresponding author: SE Ramsay, s.ramsay@ucl.ac.uk, Department of Primary Care & Population Health,
13 UCL Medical School, Royal Free Campus, Rowland Hill Street, London NW3 2PF
14

15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

Abstract

Objectives: Evidence on the extent of poor oral health in the older UK adult population is limited. We describe the prevalence of objective and subjective measures of oral health in a population-based study of older men.

Design: Cross-sectional study

Setting and participants: A representative sample of men aged 71-92 years in 2010-12 from the British Regional Heart Study initially recruited in 1978-80 from general practices across Britain. Oral health measures included number of teeth, and periodontal disease measures in index teeth in each sextant (loss of attachment, periodontal pocket, gingival bleeding). Self-reported oral health measures through postal questionnaires included self-rated oral health, oral impacts on daily life and current dry mouth experience.

Results: Among 1622 men clinically examined, 338 (20%) were edentulous and a further 808 (48%) had <21 teeth. Moderate periodontal disease was present in 735 (59%) and severe periodontal disease in 176 (14%). Prevalence of gingival bleeding was 16%. Among 2147 men who returned postal questionnaires, 35% reported fair/poor oral health; 11% reported difficulty eating due to oral health problems. 31% reported 1-2 symptoms of dry mouth and 20% reported 3-5 symptoms of dry mouth. Those with poorer oral health (no teeth, severe periodontitis, or fair/poor self-rated oral health) were more likely to live outside South England and to have a manual social class.

Conclusions: High proportions of older British men had extensive tooth loss, moderate to severe periodontal disease, fair/poor self-rated oral health and symptoms of dry mouth. Determinants of these oral health problems in older populations merit further research to reduce the burden and consequences of poor oral health in this age group.

Strengths and limitations of this study

- This study provides novel information on the burden of oral health in a community-dwelling older British population.
- Study strengths are a socially and geographically representative sample of older British men, and the use of a range of subjective and objective oral health measures.
- Limitations include limited generalisability of findings to older women and non-white ethnic groups.

Introduction

Countries such as the UK are experiencing a dramatic demographic shift with a growing population of older people. The number of people aged ≥ 65 years and ≥ 85 years in England & Wales is projected to increase by 25% and 50% respectively by 2033.¹ Increasing age is strongly associated with chronic disease and disability.¹ Poor oral health among older people is also a significant health issue given its impact on overall quality of life, nutritional intake, and well-being in older age.² Poor oral health in older age includes problems such as tooth loss and dry mouth. Although recent surveys in England, show a decline in the prevalence of edentulism (complete loss of natural teeth) over the last three decades,³ loss of some teeth in older age remains an important problem affecting eating, and quality of life.

Despite increasing research into healthy ageing and improving independence in older age, there is relatively little emphasis on oral health problems in older age. There are few population-based epidemiological studies of older people in the UK that describe the burden of oral health problems and needs in later life. Most evidence is from studies or surveys that are not specific to older people, and have limited information on oral health such as self-report of having natural teeth, or self-rated oral health.^{4,5} The National Diet and Nutrition Survey in 1994-95 was the last study to include an oral health survey of older people in Britain (aged >65 years).⁶ An improved understanding of the burden of oral health problems in the UK is urgently needed in people aged over 70 years to understand the health needs of this growing population. This study presents results from a representative sample of community-dwelling British men aged 71-92 years. We describe a range of oral health measures, both objective, such as number of teeth, periodontal disease, oral inflammation, and self-reported such as self-rated oral health, impact of oral health on daily activities and dry mouth – these assessments capture a range of dental disease and oral health problems that are particularly important in older age.

Methods

The British Regional Heart Study (BRHS) is a prospective study comprising a socially and geographically representative sample of 7735 men aged 40-59 years from one general practice in each of 24 towns representing all major British regions and who were initially examined in 1978-1980.⁷ In 2010-2012 all surviving men ($n=3137$) aged 71-92 years were invited to attend a 30-year re-examination.⁸ Ethical approval was provided by all relevant local research ethics committees. All men provided written informed consent to the investigations, which were carried out in accordance with the Declaration of Helsinki. Participants underwent a physical examination, and completed a questionnaire (at the time of examination or by post if they did not attend) providing information on their medical history and lifestyle factors. Occupational social class was based on the longest-held occupation recorded at study entry (aged 40-59 years) and comprised six social class groups - I (professionals, e.g. physicians, engineers), II (managerial, e.g. teachers, sales managers), III non-manual (semi-skilled non-manual, e.g. clerks, shop assistants), III manual (semi-skilled manual, e.g. bricklayers), IV (partly skilled, e.g. postmen) and V (unskilled, e.g. porters, general labourers). Social classes III-manual, IV and V were grouped as manual social class.

Dental measures included a count of the number of teeth, and three measures of periodontal disease – periodontal pocket, loss of attachment and bleeding on probing. Periodontal disease measures were made in six index teeth (three in the upper arch and three in the lower arch) in each sextant of the mouth (left and right first molars in the posterior sextant, and central incisor in the anterior sextant). Loss of attachment and gingival bleeding were assessed at two sites on each index tooth (mesiobuccal and distobuccal sites), and periodontal pocket depth was measured on the mesiobuccal site. A CPITN (Community Periodontal Index of Treatment Needs) probe with a 0.5mm ball-ended tip with markings at 0

1 to 3.5mm, >3.5mm to 5.5mm, and >5.5mm was used. Examiners underwent extensive training and
2 calibration including a pilot prior to the study and a calibration check during the study. Agreement between
3 examiners and the training examiner ranged from 89% to 95%. Caries was not included in the assessment
4 because of time constraints on the physical examination of participants, and because of technical
5 difficulties in obtaining standardised measures of root caries.
6
7

8
9 The questionnaire included self-reported oral health measures including presence of teeth or dentures,
10 self-rated oral health (excellent, good, fair, poor), experience of dental problems, oral impacts on daily life,
11 dry mouth and dental service use (frequency of visiting a dentist and time since last dental visit).
12 Participants were asked questions on the common dental or oral health problems experienced in the past 6
13 months including toothache or sensitivity, loose tooth or gum problems, bad position of teeth, fractured
14 tooth, loose or ill-fitting dentures, appearance of teeth. Oral health related quality of life (OHRQoL) was
15 assessed through the Oral Impact on Daily Performances (OIDP) measure.⁹ Participants were asked if in the
16 past 6 months any oral health problems caused any of the following: difficulty eating, difficulty speaking,
17 difficulty going out (for example to shop or visit someone), difficulty relaxing (including sleeping), problems
18 with smiling, laughing and showing teeth without embarrassment, emotional problems eg becoming more
19 easily upset than usual, problems enjoying the company of others (eg family, friends, neighbours). The
20 Xerostomia Inventory (XI), a validated tool to assess dry mouth and its severity, was also used in the
21 questionnaire.¹⁰ The Xerostomia Inventory questions include asking if in the past 4 weeks the participants
22 experienced the following symptoms: mouth feels dry, difficulty eating dry foods, getting up at night to
23 drink, mouth feels dry when eating a meal, sip liquids to aid swallowing food, suck sweets to relieve dry
24 mouth, difficulties swallowing certain foods, skin of face feels dry, eyes feel dry, lips feel dry, inside of nose
25 feels dry. Responses to each question were never, hardly ever, occasionally, fairly often and very often.
26
27
28
29
30

31 Statistical analyses

32 Descriptive analyses were carried out to present prevalences of different oral health measures. The
33 prevalence of periodontal disease measures were calculated according to demographic characteristics (age,
34 social class and region of residence) along with chi square tests for trend. Number of teeth was categorised
35 into – no teeth, 1-7, 7-14, 15-21 and ≥ 21 teeth. Periodontal disease was determined using the CDC Working
36 Group definition of: ‘severe’ periodontal disease as ≥ 2 sites with loss of attachment ≥ 5.5 mm (not on same
37 tooth) and ≥ 1 site with periodontal pocket depth ≥ 5.5 mm; ‘moderate’ periodontal disease as ≥ 2 sites with
38 loss of attachment ≥ 3.5 mm (not on same tooth) or ≥ 2 sites with periodontal pocket of ≥ 5.5 mm (not on
39 same tooth); and ‘no or mild disease’ as absence of ‘severe’ or ‘moderate’ disease.¹¹ For periodontal
40 pockets, we also calculated the number of sites with >3.5 mm pocket depth as a proportion of sites
41 examined to obtain the percentage of sites affected, which was further categorised into 0%, 1-20% and
42 $>20\%$ sites affected. This approach has been used in previous epidemiological studies.^{12 13} Analyses were
43 carried out using SAS version 9.3.
44
45
46
47
48

49 Results

50 A total of 1722 men (55% response rate) attended the examination. Questionnaires were completed by
51 2147 men (68% response rate). Of the 1722 men who were examined, 62 (3.6%) did not have information
52 on objective oral health measures; therefore analyses based on these measures were restricted to 1660
53 men. Of these, 338 (20%) had no natural teeth, 808 (48%) had <21 teeth and 514 (31%) had ≥ 21 teeth.
54
55

56 Table 1 presents the overall prevalence of edentulism, number of teeth, periodontal disease and gingival
57 inflammation, and according to age. Men with fewer teeth tended to be older while periodontal disease
58
59
60

measures did not vary by age. Moderate periodontal disease was present in 735 (59%) and severe periodontal disease in 176 (14%) men. The proportion of men with 1-20% sites affected by periodontal pockets >3.5mm was 15% (n=183) and >20% of sites was 29% (n=365). A small proportion (3%) had periodontal pockets >5.5mm. Gingival bleeding was present in 198 (16%) men.

Table 2 presents the prevalence of self-rated oral health and presence of natural teeth and dentures in 2147 men with questionnaire data. Overall, 35% reported fair/ poor oral health, and 19% reported no natural teeth and wearing dentures.

Figures 1 and 2 present regional and social class differences, respectively, in edentulism, periodontal disease and self-rated oral health. There were few regional differences, except for edentulism (no natural teeth), which had a lower prevalence in the South of England. The prevalence of edentulism and fair/ poor self-rated oral health was greater in manual compared to non-manual groups.

Table 3 presents other self-reported oral health problems. Overall, 12% reported pain/ discomfort in teeth and 23% tooth sensitivity. The prevalence of one or more problems related to teeth (including toothache, sensitivity, loose tooth, ill-fitting denture) was 42%. The prevalence of oral impacts on daily activities (OIDP) was 11% for difficulty eating food and 14% overall, i.e. at least one oral impact such as eating, speaking, and going out.

Table 4 presents the xerostomia inventory measure reported by the participants. In summary, 31% reported 1-2 symptoms of dry mouth (occasionally or more often), 20% reported 3-5 symptoms and 8% reported >5 symptoms of dry mouth. Combining self-reported oral health problems, oral impacts on daily activities, and dry mouth, the prevalence of one or more self-reported dental problems was 73%.

Based on questions on use of dental services, 11% reported going to a dentist only when having a problem, 15% reported that they had never gone to a dentist.

Discussion

In this study of a socially representative sample of older British men aged 71-92 years we found a high burden of oral health problems including tooth loss, periodontal disease, poor self-rated oral health, oral impacts on eating, and dry mouth. These results point to the high oral health-care needs in older populations and the need to understand and address these problems.

This study presents a range of oral health problems including objective and subjective measures in an older British population. Reports from the 10 yearly Adult Dental Health Surveys (most recently in 2009) have shown that the prevalence of edentulism (no natural teeth) in adults has declined by 22% from 1978 to 6% in 2009.^{5 14} The proportion of adults with ≥ 21 teeth has also reported to have increased from 73% in 1978 to 86% in 2009.¹⁴ The presence of ≥ 21 teeth is widely used to define a minimum functional dentition.⁵ Although, retention of teeth has improved overall in adults, tooth loss (partial or complete) increases dramatically with age and remains a significant problem in older age.¹⁴ The Adult Dental Health Survey 2009 reported the marked increased in loss of teeth in older age groups;¹⁴ of adults aged >85 years, 47% were edentate and just 14% had ≥ 21 teeth. Our results, based on men aged 71-92 years, showed a prevalence of being edentate of 20%, and that only 31% had ≥ 21 teeth.

1 We used three measures to assess periodontal disease – gingival bleeding (a marker of inflammation of the
2 gums), periodontal pockets (measures the gap between gums and tooth; a deeper pocket indicates active
3 periodontal disease), and loss of attachment (distance between the point at which the gum is attached and
4 the neck of the tooth where the gum is attached in a healthy tooth; this measures chronic destruction of
5 attachment of gums to the tooth).³ Our study of older men had a high prevalence of excess loss of
6 attachment, a longer-term measure of damage to periodontal tissue, while deep periodontal pockets and
7 gingival inflammation (indicators of active periodontal disease) were less prevalent. The Adult Dental
8 Health Survey reported higher proportions of severe (76%) and moderate loss of attachment (25%) than
9 our study;¹⁵ this could be higher since it was based on the highest measure recorded on any tooth, whereas
10 our measure based on sites limited to six index teeth. Apart from the Adult Dental Health Survey, most
11 studies on prevalence of periodontal disease and oral health in older people are from non-UK populations.
12 Variations in measurement of periodontal disease makes it difficult for comparisons between studies, with
13 few national level data on periodontal disease;¹⁶ estimates of periodontal disease in 65-74 year olds are
14 reported to range from 4% in New Zealand to 40% in Germany.¹⁶

15
16
17
18
19
20
21 Self-reported oral health problems in our study ranged from self-rated oral health to dry mouth symptoms.
22 We found that over a third of the participants reported fair or poor self-rated oral health. The most
23 prevalent oral health problems were toothache, sensitivity and ill-fitting dentures. Over 40% of subjects
24 reported one or more oral health problems. The most common oral impact was difficulty eating. In relation
25 to xerostomia, a third of participants reported that their mouth felt dry, and a third reported one or two
26 symptoms of dry mouth. Over 70% of our study population reported one or more of these problems
27 combined (problems with teeth or gums, oral impact on daily activities and dry mouth). Notably our results
28 also show that a very high prevalence (73%) of oral health problems occur in combination, such as
29 problems with teeth/ gums along with difficulty eating and dry mouth. The Adult Dental Health Survey also
30 reported high levels of self-reported oral health problems such as impact on eating, particularly in older age
31 groups.¹⁷

32
33
34
35 Socioeconomic patterns with lower number of teeth, severe periodontal disease, and higher levels of
36 fair/poor self-rated oral health in manual compared to non-manual social class groups were observed in
37 our study. Similar socioeconomic patterns have been reported in other studies.^{4 18} Determinants of the
38 socioeconomic differences in oral health in older populations needs to be further investigated.

39 40 41 Strengths and limitations

42 To our knowledge this paper presents the most recent epidemiological population-based study of oral
43 health and function in a community-dwelling older British population aged over 70 years with objective and
44 self-reported measures; there are few such data on older populations in the UK, apart from the ten yearly
45 Adult Dental Health Surveys which is conducted across the adult population, and the National Diet and
46 Nutrition Survey from 1994-95. Other studies in older populations in the UK have limited self-reported
47 measures of oral health.⁴ We present results from a socially and geographically representative sample of
48 older British men. The study has had an exceptionally high follow-up rate (98%), minimizing rates of
49 attrition. However, survivor bias is inevitable in a cohort sample of an ageing population; participants with
50 higher rates of chronic diseases would have died. The moderate response rate for the clinical examination
51 (55%) is also likely to have excluded participants in worse health (as observed in previous examinations),¹⁹
52 who are also likely to have worse oral health. Therefore, it is possible that our findings have under-reported
53 the burden of oral health in the population. Another limitation is that this study comprises only white
54 European men, and the results cannot be generalized to women and other ethnic groups. The Adult Dental
55
56
57
58
59
60

1 Health survey reported better periodontal health in women than men.³ Nevertheless, we believe the
2 results provide a valuable insight into the epidemiology and burden of oral health in the older British
3 populations.
4
5

6 Implications and conclusions

7 This study highlights the substantial burden of oral health in the older population. With the increasing
8 number of older people in the UK, oral health forms an important aspect of health in later life. Ageing
9 research currently largely focuses on managing long-term conditions and improving disability and frailty in
10 older age; there is little emphasis on oral health and its importance in improving healthy ageing. Our
11 results highlight the need to investigate determinants (biological and social) that are important in
12 improving oral health and function in later life. Population-based studies are needed to understand the
13 contribution of oral health to overall health in later life alongside other aspects of healthy ageing such as
14 disability, frailty and chronic diseases.
15
16
17
18
19

20 Author contributions: SER, SGW, PHW, RGW, GT developed the original idea for the paper. SER wrote the
21 first draft. SER and AOP performed the analyses. SER, PHW, SGW, LTL, AOP, RGW, GT contributed to the
22 study design and collation of data. All authors contributed to interpretation of data and the final version of
23 the manuscript, and all are guarantors.
24

25 Funding: The British Regional Heart Study was supported by a British Heart Foundation Programme Grant
26 (RG/08/013/25942). SER is funded by a UK MRC Fellowship (G1002391). The views expressed in this paper
27 are those of the authors and not necessarily those of the funding bodies.
28
29

30 Competing interests: None.
31

32 Ethical approval: The British Regional Heart Study has local (from each of the districts in which the study
33 was based) and multicentre ethical committee approvals.
34

35 Data sharing: Further details of the Study can be found on <http://www.ucl.ac.uk/pcph/research-groups-themes/brhs-pub>. For general data sharing enquiries, please contact Lucy Lennon l.lennon@ucl.ac.uk
36
37
38
39
40

41 References

- 42 1. Change SCOPsAD. *Ready for Ageing? Report*. London: The Stationery Office, 2013.
- 43 2. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global
44 Oral Health Programme. *Community Dent Oral Epidemiol* 2005;33:81-92.
- 45 3. White DA, Tsakos G, Pitts NB, et al. Adult Dental Health Survey 2009: common oral health conditions and
46 their impact on the population. *Br Dent J* 2012;213(11):567-72.
- 47 4. Tsakos G, Demakakos P, Breeze E, et al. Social Gradients in Oral Health in Older Adults: Findings From the
48 English Longitudinal Survey of Aging. *American Journal of Public Health* 2011;101(10):1892-99.
- 49 5. Steele JG, Treasure ET, O'Sullivan I, et al. Adult Dental Health Survey 2009: transformations in British oral
50 health 1968-2009. *Br Dent J* 2012;213(10):523-27.
- 51 6. Sheiham A, Steele JG, Marcenes W, et al. The impact of oral health on stated ability to eat certain foods;
52 Findings from the National Diet and Nutrition Survey of Older People in Great Britain. *Gerodontology*
53 1999;16(1):11-20.
- 54 7. Walker M, Whincup PH, Shaper AG. The British Regional Heart Study 1975-2004. *Int J Epidemiol*
55 2004;33:1185-92.
56
57
58
59
60

- 1 8. Lennon LT, Ramsay SE, Papacosta O, et al. Cohort Profile Update: The British Regional Heart Study 1978-
2 2014: 35 years follow-up of cardiovascular disease and ageing. *International Journal of Epidemiology* In
3 Press.
- 4 9. Tsakos G, Marcenes W, Sheiham A. Evaluation of a modified version of the index of Oral Impacts On Daily
5 Performances (OIDP) in elderly populations in two European countries. *Gerodontology* 2001;18(2):121-30.
- 6 10. Thomson WM. Measuring change in dry-mouth symptoms over time using the Xerostomia Inventory.
7 *Gerodontology* 2007;24:30-35.
- 8 11. Eke PI, Page RC, Wei L, et al. Update of the Case Definitions for Population-Based Surveillance of
9 Periodontitis. *Journal of Periodontology* 2012;83(12):1449-54.
- 10 12. Carlos JP, Wolfe MD, Kingman A. The extent and severity index: a simple method for use in
11 epidemiologic studies of periodontal disease. *J Clin Periodontol* 1986;13(5):500-5.
- 12 13. Weyant RJ, Newman AB, Kritchevsky SB, et al. Periodontal Disease and Weight Loss in Older Adults.
13 *Journal of the American Geriatrics Society* 2004;52(4):547-53.
- 14 14. Fuller E, Steele J, Watt R, et al. Oral health and function – a report from the Adult Dental Health Survey
15 2009. *Adult Dental Health Survey 2009, 2011.*
- 16 15. White D, Pitts N, Steele J, et al. *Disease and related disorders – a report from the Adult Dental Health*
17 *Survey 2009, 2011.*
- 18 16. Thomson WM. Epidemiology of oral health conditions in older people. *Gerodontology* 2014;31:9-16.
- 19 17. Nuttall N, Tsakos G, Lader D, et al. *Outcome and impact – a report from the Adult Dental Health Survey*
20 *2009: NHS Information Centre, 2011.*
- 21 18. Steele J, Shen J, Tsakos G, et al. The Interplay between Socioeconomic Inequalities and Clinical Oral
22 Health. *Journal of Dental Research* 2015;94(1):19-26.
- 23 19. Thomas MC, Walker M, Lennon LT, et al. Non-attendance at re-examination 20 years after screening in
24 the British Regional Heart Study. *Journal of Public Health* 2002;24(4):285-91.
- 25
- 26
- 27
- 28
- 29
- 30
- 31
- 32
- 33
- 34
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

Table 1 Number of teeth and periodontal disease in a population based study of 1660 older British men aged 71-92 years in 2010-2012 in the British Regional Heart Study and sociodemographic factors

	N (%)	Mean age in years (SD)
No teeth	338 (20%)	80 (5)
1-7 teeth	123 (7%)	80 (5)
7-14 teeth	265 (16%)	79 (5)
15-21	420 (25%)	78 (4)
≥21 teeth	514 (31%)	77 (4)
P for trend		<0.0001
Periodontal disease based on loss of attachment and pocket depth*		
No disease/ mild	334 (27%)	78 (4)
Moderate	735 (59%)	78 (4)
Severe	176 (14%)	78 (4)
P for trend	-	0.27
Periodontal pocket depth - % sites >3.5mm pocket depth		
0%	697 (56%)	78 (5)
1-20%	183 (15%)	78 (4)
>20%	365 (29%)	78 (4)
P for trend	-	0.64
Gingival bleeding		
No gingival bleeding	1015 (84%)	78 (4)
Presence of gingival bleeding	198 (16%)	78 (4)

*Severe = 2 or > sites, not on same tooth, with loss of attachment (LoA) >5.5mm and pocket depth > 3.5mm

Moderate = 2 or more sites, not on same tooth, with LoA >3.5mm OR pocket depth >3.5mm

No disease/ mild = all except severe and moderate

Table 2 Self-reported oral health in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study and sociodemographic factors

	N (%)	Mean age in years (SD)
Self-rated oral health		
Excellent	271 (13%)	79 (5)
Good	1049 (51%)	78 (5)
Fair	587 (29%)	79 (5)
Poor	132 (6%)	79 (5)
P for trend		0.07
Natural teeth and dentures		
Only natural teeth	797 (38%)	79 (4)
Natural teeth and dentures	882 (42%)	79 (5)
No natural teeth, and wear dentures	407 (19%)	80 (5)
No natural teeth or dentures	14 (1%)	80 (5)
P for trend		<0.0001

Figure 1: Prevalence of oral health outcomes by region in a population based study of 1660 men aged 71-92 years in 2010-12 in the British Regional Heart Study

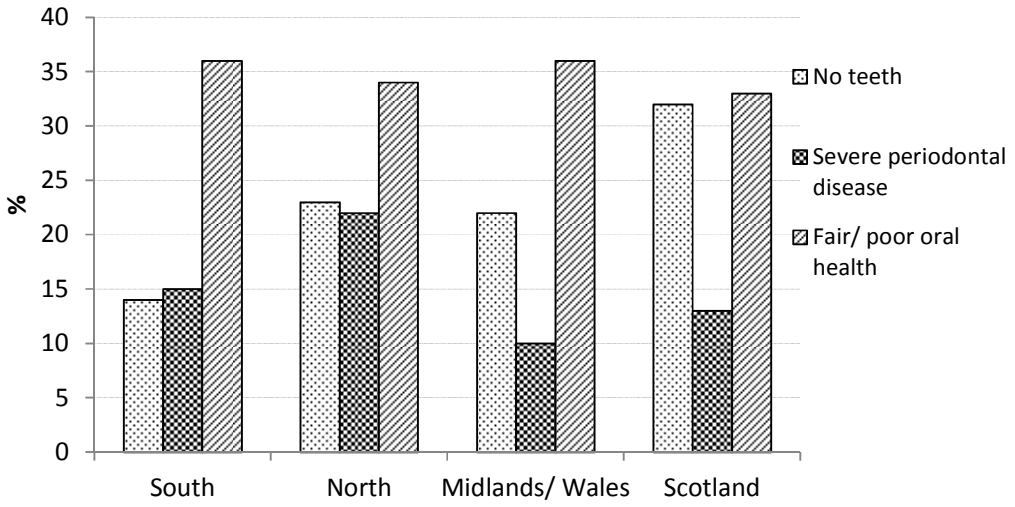


Figure 2: Prevalence of oral health outcomes by social class in a population based study of 1660 men aged 71-92 years in 2010-12 in the British Regional Heart Study

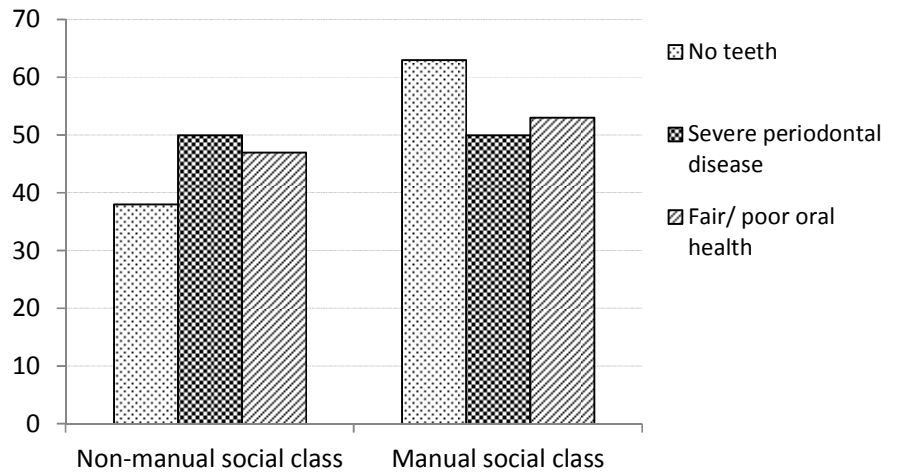


Table 3: Prevalence of self-reported dental problems in a population based study of 2147 British men aged 71-92 years in 2010-12 in the British Regional Heart Study

Toothache/ discomfort	N (%)
Pain or discomfort with teeth	233 (12%)
Sensitivity to hot/cold/sweets	453 (23%)
Dental problems	
Toothache, sensitivity, decay	538 (25%)
Loose tooth, or gum problems	246 (11%)
Bad position of teeth	64 (3%)
Ill-fitting denture or fractured tooth	277 (13%)
One or more of the above problems	908 (42%)
Impact on daily life due to dental problems	
Difficulty eating food	231 (11%)
Difficulty speaking	67 (3%)
Difficulty going out (for eg to shop or visit someone)	29 (1%)
Difficulty relaxing (eg sleeping)	31 (1%)
Problems with smiling, laughing without embarrassment	83 (4%)
Emotional problems (eg becoming more easily upset than usual)	26 (1%)
Problems enjoying the company of others (eg. family, friends)	31 (1%)
One or more of the above problems	304 (14%)

Table 4 Xerostomia (dry mouth) inventory (XI) in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study

	Never N (%)	Hardly ever N (%)	Occasionally N (%)	Fairly often N (%)	Very often N (%)
My mouth feels dry	963 (45)	449 (21)	516 (24)	149 (7)	70 (3)
I have difficulty in eating dry foods	1676 (78)	261 (12)	149 (7)	44 (2)	17 (1)
I get up at night to drink	1318 (61)	276 (13)	378 (18)	116 (5)	59 (3)
My mouth feels dry when eating a meal	1736 (81)	263 (12)	112 (5)	26 (1)	10 (0.50)
I sip liquids to aid in swallowing food	1687 (79)	192 (9)	187 (9)	55 (3)	26 (1)
I suck sweets or cough lollies to relieve dry mouth	1689 (79)	176 (8)	224 (10)	41 (2)	17 (1)
I have difficulties swallowing certain foods	1798 (84)	175 (8)	123 (6)	34 (2)	17 (1)
The skin of my face feels dry	1747 (81)	169 (8)	141 (7)	60 (3)	30 (1)
My eyes feel dry	1585 (74)	172 (8)	260 (12)	86 (4)	44 (2)
My lips feel dry	1480 (70)	241 (11)	321 (15)	81 (4)	24 (1)
The inside of my nose feels dry	1535 (72)	239 (11)	278 (13)	71 (3)	24 (1)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Checklist for the manuscript	Page number
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Yes	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Yes	2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Yes	3
Objectives	3	State specific objectives, including any prespecified hypotheses	Yes	3
Methods				
Study design	4	Present key elements of study design early in the paper	Yes	3, 4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Yes	3, 4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Yes	3, 4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Yes	3, 4
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Yes	3, 4
Bias	9	Describe any efforts to address potential sources of bias	Yes	3, 4
Study size	10	Explain how the study size was arrived at	Yes	3, 4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Yes	4
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Yes	4
		(b) Describe any methods used to examine subgroups and	Yes	4

1			
2	interactions		
3	(c) Explain how missing data were addressed	Yes	4, 9
4	(d) <i>Cohort study</i> —If applicable, explain how loss to follow-	Yes	4
5	up was addressed		
6	<i>Case-control study</i> —If applicable, explain how matching of		
7	cases and controls was addressed		
8	<i>Cross-sectional study</i> —If applicable, describe analytical		
9	methods taking account of sampling strategy		
10			
11	(e) Describe any sensitivity analyses	N/A	N/A
12			

Continued on next page

For peer review only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Results		Checklist for the manuscript	Page number
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Yes 4, 5
		(b) Give reasons for non-participation at each stage	Yes 4, 5
		(c) Consider use of a flow diagram	Numbers given in text. 4, 5
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Yes 5, 9
		(b) Indicate number of participants with missing data for each variable of interest	Yes Tables 1 to 4
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Yes Tables 1 to 4
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A N/A
		(b) Report category boundaries when continuous variables were categorized	N/A N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Yes 5 and figures 1 and 2
Discussion			
Key results	18	Summarise key results with reference to study objectives	Yes 5
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Yes 6
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Yes 6, 7
Generalisability	21	Discuss the generalisability (external validity) of the study results	Yes 6, 7
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on	Yes 7

1
2 which the present article is based
3

4 *Give information separately for cases and controls in case-control studies and, if applicable, for exposed and
5 unexposed groups in cohort and cross-sectional studies.
6
7

8 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and
9 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely
10 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at
11 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is
12 available at www.strobe-statement.org.
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

BMJ Open

The Burden of Poor Oral Health in Older Age: Findings from a Population-based Study of Older British Men

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2015-009476.R1
Article Type:	Research
Date Submitted by the Author:	08-Oct-2015
Complete List of Authors:	Ramsay, Sheena; UCL, Primary Care & Population Health Whincup, Peter; St Georges, University of London, Population Health Research Institute Watt, Richard; UCL, Epidemiology and Public Health Tsakos, Georgios; UCL, Epidemiology and Public Health Papacosta, Olia; UCL, Department of Primary Care and Population Health Lennon, Lucy; UCL, Department of Primary Care and Population Health Wannamethee, Goya; UCL, Department of Primary Care and Population Health
Primary Subject Heading:	Dentistry and oral medicine
Secondary Subject Heading:	Epidemiology, Public health, Geriatric medicine
Keywords:	EPIDEMIOLOGY, ORAL MEDICINE, PUBLIC HEALTH, GERIATRIC MEDICINE

SCHOLARONE™
Manuscripts

1
2 **The Burden of Poor Oral Health in Older Age: Findings from a Population-based Study of Older**
3 **British Men**
4

5
6
7 SE Ramsay,¹ PH Whincup,² RG Watt,³ G Tsakos,³ AO Papacosta,¹ LT Lennon,¹ SG Wannamethee¹

8
9 ¹Department of Primary Care & Population Health, UCL, London, UK

10 ²Population Health Research Institute, St George's University of London, London, UK

11 ³Department of Epidemiology & Public Health, UCL, London, UK
12
13

14
15 Corresponding author: SE Ramsay, s.ramsay@ucl.ac.uk, Department of Primary Care & Population Health,
16 UCL Medical School, Royal Free Campus, Rowland Hill Street, London NW3 2PF
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

Objectives: Evidence on the extent of poor oral health in the older UK adult population is limited. We describe the prevalence of oral health conditions, using objective clinical and subjective measures, in a population-based study of older men.

Design: Cross-sectional study

Setting and participants: A representative sample of men aged 71-92 years in 2010-12 from the British Regional Heart Study initially recruited in 1978-80 from general practices across Britain. Physical examination among 1660 men included oral health measures in terms of number of teeth, and periodontal disease measures in index teeth in each sextant (loss of attachment, periodontal pocket, gingival bleeding). Postal questionnaires (completed by 2147 men including all participants who were clinically examined) included self-rated oral health, oral impacts on daily life and current perception of dry mouth experience.

Results: Among 1660 men clinically examined, 338 (20%) were edentulous and a further 728 (43%) had <21 teeth. For periodontal disease, 233 (19%) had increased loss of attachment (>5.5mm) affecting 1-20% sites while 303 (24%) had >20% sites affected. The prevalence of gingival bleeding was 16%. Among 2147 men who returned postal questionnaires, 35% reported fair/poor oral health; 11% reported difficulty eating due to oral health problems. 31% reported 1-2 symptoms of dry mouth and 20% reported 3-5 symptoms of dry mouth. The prevalence of edentulism, increased loss of attachment, or fair/poor self-rated oral health was greater in those from manual social class.

Conclusions: These findings highlight the high burden of poor oral health in older British men. This was reflected in both the objective clinical and subjective measures of oral health conditions. The determinants of these oral health problems in older populations merit further research to reduce the burden and consequences of poor oral health in older people.

Strengths and limitations of this study

- This study provides novel information on the burden of oral health in a community-dwelling older British population.
- Study strengths are a socially and geographically representative sample of older British men, and the use of a range of subjective and objective clinical oral health measures.
- Limitations include limited generalisability of findings to older women and non-white ethnic groups.

Introduction

Countries such as the UK are experiencing a dramatic demographic shift with a growing population of older people. The number of people aged ≥ 65 years and ≥ 85 years in England and Wales is projected to increase by 25% and 50% respectively by 2033.¹ These patterns of an ageing population in the UK and other countries have important public health implications,² as increasing age is strongly associated with chronic disease and disability.¹ Therefore, there is a greater imperative to prevent and manage chronic diseases and maintain optimal functioning in older people.² Despite increasing research into healthy ageing and improving independence in older age, there is relatively less emphasis on oral health problems which have a significant impact on quality of life, nutritional intake, and well-being in older age.³ The Global Burden of Disease 2010 Study showed that oral health problems accounted for 15 million disability adjusted life years, implying an average health loss of 224 years per 100,000 population;⁴ furthermore, due to population ageing, the burden of oral health problems increased from 1990 to 2010.⁴ The burden of oral health problems, particularly from periodontal (gum) disease and tooth loss, increases with age.⁴ A review of the epidemiology of oral health conditions in older people highlights the burden of conditions including tooth loss and dry mouth in older people.⁵ Although edentulism (complete loss of natural teeth) has declined in recent decades in several countries,⁵ a significant number of older people are still edentulous (2.7 million in the UK in 2009),⁶ and partial tooth loss remains an important problem affecting eating, quality of life and adding to complexities in rehabilitation in older people.

In order to effectively address the issues of poor oral health in older people it is important to understand the extent of the problem. There are few population-based epidemiological studies of older people in the UK that describe the burden of oral health problems and needs in later life. Most evidence is from studies or surveys that are not specific to older people such as the Adult Dental Health Survey,⁸ or have limited information on oral health such as self-report of having natural teeth, or self-rated oral health as in the English Longitudinal Study of Ageing.^{7,8} The National Diet and Nutrition Survey in 1994-95 was the last study specifically in older people in Britain (aged >65 years) that included an oral health examination.⁹ An improved understanding of the burden of oral health problems in the UK is urgently needed in people aged over 70 years to understand the health needs of this growing population. This aim of this study was to describe the burden of poor oral health in a representative population-based sample of community-dwelling British men aged 71-92 years. We describe a range of oral health conditions based on, both objective clinical measures, such as number of teeth, periodontal disease, oral inflammation, and also subjective measures such as self-rated oral health, impact of oral health on daily activities and dry mouth – these assessments capture a range of dental diseases and oral health conditions that are particularly important in older age.

Methods

The British Regional Heart Study (BRHS) is a prospective study comprising a socially and geographically representative sample of 7735 men aged 40-59 years from one general practice in each of 24 towns representing all major British regions and who were initially examined in 1978-1980.¹⁰ In 2010-2012 all surviving men (n=3137, 41%) aged 71-92 years were invited to attend a 30-year re-examination.¹¹ Ethical approval was provided by all relevant local research ethics committees. All participating men provided written informed consent to the investigations, which were carried out in accordance with the Declaration of Helsinki. Participants underwent a physical examination, and completed a questionnaire (at the time of examination or sent by post if they did not attend the examination) providing information on their medical history and lifestyle factors. Occupational social class was based on the longest-held occupation recorded at study entry (aged 40-59 years) and comprised six social class groups - I (professionals, e.g. physicians, engineers), II (managerial, e.g. teachers, sales managers), III non-manual (semi-skilled non-manual, e.g. clerks, shop assistants), III manual (semi-skilled manual, e.g. bricklayers), IV (partly skilled, e.g. postmen) and V (unskilled, e.g. porters, general labourers). For the purposes of this study, social classes III-manual, IV and V were grouped as manual social class and those from Armed Forces were not included (n=63).

The physical examination of participants in 2010-12, when aged 71-92 years, included for the first time, a brief oral health assessment. Dental measures included a count of the number of teeth, and three measures of periodontal disease – periodontal pocket depth (measures the gap between gums and tooth, loss of attachment (the distance between the point at which the gum is attached and the “neck” of the tooth where the gum is attached in a healthy tooth), and bleeding on probing (a marker of current inflammation of the gums). Periodontal disease measures were made in six index teeth (three in the upper arch and three in the lower arch), one per sextant of the mouth. First molars were measured in the four posterior sextants, and right central incisors in the two anterior sextants; where the first molar was missing, the following tooth was chosen in order of priority: second premolar, first premolar, second molar; if the central incisor was missing, the next mesial tooth available in that sextant was chosen. Loss of attachment and gingival bleeding were assessed at two sites (mesiobuccal and distobuccal) on each index tooth, and periodontal pocket depth was measured on the mesiobuccal site. A CPITN (Community Periodontal Index of Treatment Needs) probe with a 0.5mm ball-ended tip with markings at 0 to 3.5mm, >3.5mm to 5.5mm, and >5.5mm was used. Examiners (research nurses) underwent extensive training and calibration including a pilot prior to the study and a calibration check during the study. Agreement was tested between each examiner and the training examiner (dental surgeon) for every reading for the three periodontal disease measures (loss of attachment, periodontal pocket depth, gingival bleeding). Examiner and trainer agreement ranged from 89% to 95% (closest agreement was for gingival bleeding), and median Kappa index was 0.79. It was not possible to include other measures of dental disease such as dental caries in the dental examination because of time constraints on the physical examination of participants. The dental

1 examination was part of an extensive physical examination. Given the advanced age of the participants (71-
2 92 years) it was important to avoid participant burden and therefore, only a very brief dental examination
3 was possible.
4
5

6
7
8 The questionnaire included self-reported oral health measures: presence of teeth or dentures, self-rated
9 oral health (excellent, good, fair, poor), experience of dental problems, oral impacts on daily life, dry mouth
10 and dental service use (frequency of visiting a dentist and time since last dental visit). Participants were
11 asked questions on common dental or oral health problems experienced in the past 6 months, including
12 toothache or sensitivity, loose tooth or gum problems, bad position of teeth, fractured tooth, loose or ill-
13 fitting dentures, appearance of teeth. Oral health related quality of life (OHRQoL) was assessed through the
14 Oral Impact on Daily Performances (OIDP) measure.¹² Participants were asked if in the past 6 months any
15 oral health problems caused any of the following: difficulty eating, difficulty speaking, difficulty going out
16 (for example to shop or visit someone), difficulty relaxing (including sleeping), problems with smiling,
17 laughing and showing teeth without embarrassment, emotional problems such as becoming more easily
18 upset than usual, problems enjoying the company of others (for example, family, friends, neighbours). The
19 Xerostomia Inventory (XI), a validated tool to assess dry mouth and its severity, was also used in the
20 questionnaire.¹³ The Xerostomia Inventory questions include asking if in the past 4 weeks the participants
21 experienced the following symptoms: mouth feels dry, difficulty eating dry foods, getting up at night to
22 drink, mouth feels dry when eating a meal, sip liquids to aid swallowing food, suck sweets to relieve dry
23 mouth, difficulties swallowing certain foods, skin of face feels dry, eyes feel dry, lips feel dry, inside of nose
24 feels dry. Responses to each question were never, hardly ever, occasionally, fairly often and very often.
25
26
27
28
29
30
31
32
33
34
35

36 Statistical analyses

37
38 Descriptive analyses were carried out to present the prevalence of different oral health measures. Number
39 of teeth was categorised into – no teeth, 1-7, >7-14, 15-20 and >21 teeth.¹⁴ Periodontal disease based on
40 loss of attachment was categorised based on the proportion of sites with >5.5mm; this was calculated as
41 the number of sites affected with a loss of attachment of >5.5mm as a proportion of sites examined, and
42 categorised as 0%, 1-20% and >20% sites affected. For periodontal pockets, we calculated the number of
43 sites with >3.5mm pocket depth as a proportion of sites examined to obtain the percentage of sites
44 affected, which was further categorised into 0%, 1-20% and >20% sites affected. This approach has been
45 used in previous epidemiological studies.^{15 16} The prevalence of number of teeth, periodontal disease
46 measures and self-reported oral health conditions were calculated according to demographic
47 characteristics (age, social class and region of residence). Chi-squared tests were used to assess the
48 prevalence of oral health conditions according to age group, social class and region. Age was categorised
49 into two groups of 71-79 years and 80-92 years. Social class was used as two categories of non-manual and
50 manual. Region was based on the town of residence and categorised into groups of the four British regions
51
52
53
54
55
56
57
58
59
60

1 represented in the study – South of England, Wales/ Midlands, North of England and Scotland. Analyses
2 were carried out using SAS version 9.3.
3
4
5

6 7 **Results**

8 A total of 1722 men (55% response rate) attended the examination. Questionnaires were completed by
9 2147 men (68% response rate), including all those who attended the examination. Overall, the mean age of
10 the study population was 78 years, and 47% were from manual social class. Compared to the men to
11 responded to the questionnaire, the non-responders were older (mean age 80 years), and had a higher
12 proportion of manual social classes (61%). Based on data from a previous follow-up, the non-responders
13 also had higher levels of poor/fair self-rated health (27%) compared to responders (16%).
14
15
16
17
18

19 Of the 1722 men who were examined, 62 (3.6%) did not have information on objective clinical oral health
20 measures; therefore analyses based on these measures were restricted to 1660 men. Of these, 338 (20%)
21 had no natural teeth, 728 (43%) had 1-20 teeth and 594 (36%) had ≥ 21 teeth. Table 1 presents the overall
22 prevalence of edentulism, number of teeth, periodontal disease and gingival inflammation, and also by age
23 groups, social class and region. Overall, 20% men were edentulous. The prevalence of edentulism was
24 greater in the older age group (80-92 years), in manual social classes and in those from Scotland.
25 Periodontal disease measures were conducted in 1246 dentate men (those with natural teeth). Overall,
26 43% men (n=536) had a loss of attachment >5.5 mm; 24% (n=303) of men had $>20\%$ of sites affected by loss
27 of attachment of 5.5mm and 19% with 1-20% sites. Overall, 44% of men had a periodontal pocket >3.5 mm.
28 The proportion of men with 1-20% sites affected by periodontal pockets >3.5 mm was 15% (n=183) and
29 $>20\%$ of sites was 29% (n=365). A small proportion (3%) had periodontal pockets >5.5 mm. Gingival bleeding
30 was present in 198 (16%) men. The older age group (80-92 years) and manual social classes had a higher
31 prevalence of increased loss of attachment and increased pocket depth ($>20\%$ sites affected) compared to
32 subjects aged 71-79 years and those of non-manual social classes. For region, those in the North of England
33 had a lower prevalence of increased loss of attachment and periodontal pockets compared to those from
34 other regions. The prevalence of gingival bleeding did not vary by age, social class or region.
35
36
37
38
39
40
41
42
43
44
45

46 Table 2 presents the prevalence of self-rated oral health and presence of natural teeth and dentures in
47 2147 men with questionnaire data. Overall, 35% reported fair/ poor oral health, and 19% reported no
48 natural teeth and wearing dentures. The prevalence of reporting fair/ poor self-rated oral health was higher
49 in older subjects and manual social classes, but did not vary by region. The self-report of having no natural
50 teeth and wearing dentures was higher in older subjects, manual social classes and those from Scotland.
51
52
53
54
55
56
57
58
59
60

1 Table 3 presents other self-reported oral health problems. Overall, 25% reported having had problems of
2 toothache, sensitivity and tooth decay. The prevalence of one or more problems related to teeth (including
3 toothache, sensitivity, loose tooth, ill-fitting denture) was 42%. Reporting one or more of such problems
4 was lower in manual social classes ($p=0.007$), but did not differ significantly between the two age groups
5 ($p=0.35$) or by region ($p=0.11$). The prevalence of oral impacts on daily performances (OIDP) was 11% for
6 difficulty eating food and 14% overall (at least one oral impact such as eating, speaking, and going out). The
7 prevalence of one or more oral impacts was higher in older subjects ($p=0.001$), but did not differ
8 significantly by social class ($p=0.01$) or region ($p=0.18$).
9

10 Table 4 presents the xerostomia inventory measure reported by the participants. The mean xerostomia
11 score was 16 (SD 6). Overall, 34% reported that their mouth feels dry (occasionally or more often). To
12 summarise the xerostomia inventory based on symptoms reported as occasionally, fairly often or very
13 often, 31% reported 1-2 symptoms of the xerostomia inventory, 20% reported 3-5 symptoms and 8%
14 reported >5 symptoms. Combining self-reported oral health problems, oral impacts on daily activities, and
15 dry mouth, the prevalence of one or more self-reported dental problems was 73%.
16

17 Based on questions on use of dental services, 11% reported going to a dentist only when having a problem,
18 15% reported that they had never gone to a dentist.
19

20 Discussion

21 In this study we aim to describe the burden of poor oral health in a socially representative sample of older
22 British men aged 71-92 years. Our findings show a high burden of oral health problems including tooth loss,
23 periodontal disease, poor self-rated oral health, oral impacts on eating, and dry mouth. Several of these
24 oral health conditions including complete tooth loss, periodontal disease and poor self-rated oral health
25 were greater in lower social classes and the older old age groups. These findings emphasise the high oral
26 health-care needs in older populations and the need to understand ways to prevent and manage these
27 problems.
28

29 Strengths and limitations

30 To our knowledge this paper presents the most recent epidemiological population-based study of oral
31 health and function in a community-dwelling older British population aged over 70 years with objective
32 clinical and self-reported measures; there are few such data on older populations in the UK, apart from the
33 ten yearly Adult Dental Health Surveys which is conducted across the adult population, and the National
34 Diet and Nutrition Survey from 1994-95. Other studies in older populations in the UK have limited self-
35 reported measures of oral health.⁷ We present results from a cross-sectional study of a socially and
36 geographically representative cohort of older British men. However, survivor bias is inevitable in a cohort
37 study.
38

1 sample of an ageing population; participants with higher rates of chronic diseases would have died. The
2 moderate response rate for the clinical examination (55%) is also likely to have excluded participants in
3 worse health. As observed in previous examinations,¹⁷ non-responders, compared to responders, were
4 older and had higher proportions of manual social class and poor/fair self-rated overall health, which are
5 also likely to be related to having worse oral health. Therefore, it is possible that our findings have under-
6 estimated the burden of oral health in the older population. Another limitation is that this study comprises
7 only white European men, and the results cannot be generalized to women and other ethnic groups. The
8 Adult Dental Health survey reported better periodontal health in women than men.⁶ Nevertheless, we
9 believe the results provide a valuable insight into the epidemiology and burden of oral health in the older
10 British populations.

11 Reports from the 10 yearly Adult Dental Health Surveys (most recently in 2009) have shown that the
12 prevalence of edentulism (no natural teeth) in adults has declined by 22% from 1978 to 6% in 2009.^{8,18} The
13 proportion of adults with ≥ 21 teeth (widely used to define a minimum functional dentition), has also
14 reported to have increased from 73% in 1978 to 86% in 2009.¹⁸ These patterns have also been observed in
15 countries other than the UK.⁵ In the National Diet and Nutrition Survey of 1994-95, 45% of free-living adults
16 aged >65 years were edentulous.¹⁹ Although, retention of teeth has improved overall in adults, tooth loss
17 (partial or complete) increases dramatically with age and remains a significant problem in older age.¹⁸ The
18 Adult Dental Health Survey 2009 documented the marked increase in loss of teeth in older age groups;¹⁸
19 the prevalence of edentulism was 30% in adults aged 75-84 years and 47% in those aged >85 years. In the
20 English Longitudinal Study of Ageing 26% of men and women >60 years in 2002-2003 reported having no
21 natural teeth.²⁰ Our results, based on men aged 71-92 years, showed a prevalence of being edentate of
22 20%, and that only 31% had ≥ 21 teeth.

23 We used three measures to assess periodontal disease – gingival bleeding (a marker of current
24 inflammation of the gums), periodontal pockets (a deeper pocket indicates active periodontal disease), and
25 loss of attachment (a marker of experience of periodontal disease).⁶ Our study of older men had a high
26 prevalence of excess loss of attachment, a longer-term measure of damage to periodontal tissue, while
27 deep periodontal pockets and gingival inflammation (indicators of active periodontal disease) were less
28 prevalent. The Adult Dental Health Survey reported higher proportions of severe (76%) and moderate loss
29 of attachment (25%) than our study;²¹ this could be higher since it was based on the highest measure
30 recorded on any tooth, whereas our measure based on sites limited to six index teeth. Apart from the Adult
31 Dental Health Survey, most studies on prevalence of periodontal disease and oral health in older people are
32 from non-UK populations. Variations in measurement of periodontal disease makes it difficult for
33 comparisons between studies, with few national level data on periodontal disease;⁵ estimates of
34 periodontal disease in 65-74 year olds are reported to range from 4% in New Zealand to 40% in Germany.⁵

1 Self-reported oral health problems in our study ranged from self-rated oral health to dry mouth symptoms.
2
3 We found that over a third of the participants reported fair or poor self-rated oral health. The most
4 prevalent oral health problems were toothache, sensitivity and ill-fitting dentures. Over 40% of subjects
5 reported one or more oral health problems. The most common oral impact was difficulty eating. In relation
6 to xerostomia, a third of participants reported that their mouth felt dry, and a third reported one or two
7 symptoms of dry mouth. Over 70% of our study population reported one or more of these problems
8 combined (problems with teeth or gums, oral impact on daily activities and dry mouth). Notably our results
9 also show that a very high prevalence (73%) of oral health problems occur in combination, such as
10 problems with teeth/ gums along with difficulty eating and dry mouth. The Adult Dental Health Survey also
11 reported high levels of self-reported oral health problems such as impact on eating, particularly in older age
12 groups.²²

13
14
15
16
17
18
19
20
21 The prevalence of most oral health conditions (edentulism, lower number of teeth, severe periodontal
22 disease, and higher levels of fair/poor self-rated oral health) was greater in manual (or lower
23 socioeconomic groups) compared to non-manual social class groups in our study. Similar socioeconomic
24 patterns have been reported in other British studies.^{7 23} Determinants of these socioeconomic differences
25 in oral health in older populations need to be further investigated. Regional differences were most
26 markedly observed for edentulism with lowest levels in South of England and highest in Scotland. This is in
27 keeping with lower levels of other diseases (such as cardiovascular disease) in South of England and higher
28 levels in Scotland.²⁴

34 35 36 Implications and conclusions

37 This study highlights the substantial burden of oral health in the older population which has important
38 implications for public health policy, clinical practice, and research. Improving the health of an increasingly
39 ageing population needs to address the oral health problems in this population, particularly in those from
40 lower socioeconomic groups. Treatment and management of oral health problems in older people is
41 further complicated by age-related changes in the mouth, the presence of co-morbidities and issues of
42 access to dental care.^{25 26} Care pathways for oral healthcare of older people needs to adapt to the needs of
43 older people.²⁷ Ageing research also currently largely focuses on managing long-term conditions and
44 improving disability and frailty in older age; there is little emphasis on preventing oral health problems in
45 later life and its importance in improving healthy ageing. There remains a need to investigate determinants
46 (biological and social) that are important in improving oral health and function in later life. Population-
47 based studies are also needed to understand the contribution of oral health to overall health in later life
48 alongside other aspects of healthy ageing such as disability, frailty and chronic diseases.

1 Author contributions: SER, SGW, PHW, RGW, GT developed the original idea for the paper. SER wrote the
2 first draft. SER and AOP performed the analyses. SER, PHW, SGW, LTL, AOP, RGW, GT contributed to the
3 study design and collation of data. All authors contributed to interpretation of data and the final version of
4 the manuscript, and all are guarantors.
5
6
7

8
9 Funding: The British Regional Heart Study was supported by a British Heart Foundation Programme Grant
10 (RG/08/013/25942). SER is funded by a UK MRC Fellowship (G1002391). The views expressed in this paper
11 are those of the authors and not necessarily those of the funding bodies.
12
13

14 Competing interests: No, there are no competing interests.
15

16
17 Ethical approval: The British Regional Heart Study has local (from each of the districts in which the study
18 was based) and multicentre ethical committee approvals.
19

20 Data sharing: No additional data available.
21
22
23
24
25

26 References

- 27 1. Change SCOPsAD. *Ready for Ageing? Report*. London: The Stationery Office, 2013.
- 28 2. Beard JR, Bloom DE. Towards a comprehensive public health response to population ageing. *The Lancet*
29 2015;**385**(9968):658-61.
- 30 3. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global
31 Oral Health Programme. *Community Dent Oral Epidemiol* 2005;**33**:81-92.
- 32 4. Marcenes W, Kassebaum NJ, Bernabe E, et al. Global burden of oral conditions in 1990-2010: a
33 systematic analysis. *J Dent Res* 2013;**92**(7):592-7.
- 34 5. Thomson WM. Epidemiology of oral health conditions in older people. *Gerodontology* 2014;**31**:9-16.
- 35 6. White DA, Tsakos G, Pitts NB, et al. Adult Dental Health Survey 2009: common oral health conditions and
36 their impact on the population. *Br Dent J* 2012;**213**(11):567-72.
- 37 7. Tsakos G, Demakakos P, Breeze E, et al. Social Gradients in Oral Health in Older Adults: Findings From the
38 English Longitudinal Survey of Aging. *American Journal of Public Health* 2011;**101**(10):1892-99.
- 39 8. Steele JG, Treasure ET, O'Sullivan I, et al. Adult Dental Health Survey 2009: transformations in British oral
40 health 1968-2009. *Br Dent J* 2012;**213**(10):523-27.
- 41 9. Sheiham A, Steele JG, Marcenes W, et al. The impact of oral health on stated ability to eat certain foods;
42 Findings from the National Diet and Nutrition Survey of Older People in Great Britain. *Gerodontology*
43 1999;**16**(1):11-20.
- 44 10. Walker M, Whincup PH, Shaper AG. The British Regional Heart Study 1975-2004. *Int J Epidemiol*
45 2004;**33**:1185-92.
- 46 11. Lennon LT, Ramsay SE, Papacosta O, et al. Cohort Profile Update: The British Regional Heart Study 1978-
47 2014: 35 years follow-up of cardiovascular disease and ageing. *International Journal of Epidemiology*
48 2015;**44**:826-26g.
- 49 12. Tsakos G, Marcenes W, Sheiham A. Evaluation of a modified version of the index of Oral Impacts On
50 Daily Performances (OIDP) in elderly populations in two European countries. *Gerodontology*
51 2001;**18**(2):121-30.
- 52 13. Thomson WM, Chalmers JM, Spencer AJ, et al. The Xerostomia Inventory: a multi-item approach to
53 measuring dry mouth. *Community Dent Health* 1999;**16**(1):12-7.
- 54 14. Eke PI, Page RC, Wei L, et al. Update of the Case Definitions for Population-Based Surveillance of
55 Periodontitis. *Journal of Periodontology* 2012;**83**(12):1449-54.
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
15. Carlos JP, Wolfe MD, Kingman A. The extent and severity index: a simple method for use in epidemiologic studies of periodontal disease. *J Clin Periodontol* 1986;**13**(5):500-5.
16. Weyant RJ, Newman AB, Kritchevsky SB, et al. Periodontal Disease and Weight Loss in Older Adults. *Journal of the American Geriatrics Society* 2004;**52**(4):547-53.
17. Thomas MC, Walker M, Lennon LT, et al. Non-attendance at re-examination 20 years after screening in the British Regional Heart Study. *Journal of Public Health* 2002;**24**(4):285-91.
18. Fuller E, Steele J, Watt R, et al. Oral health and function – a report from the Adult Dental Health Survey 2009. *Adult Dental Health Survey 2009*, 2011.
19. Sheiham A, Steele JG, Marcenes W, et al. The relationship between oral health status and Body Mass Index among older people: a national survey of older people in Great Britain. *Br Dent J* 2002;**192**:703-06.
20. Tsakos G, Watt RG, Rouxel PL, et al. Tooth Loss Associated with Physical and Cognitive Decline in Older Adults. *Journal of the American Geriatrics Society* 2015;**63**(1):91-99.
21. White D, Pitts N, Steele J, et al. *Disease and related disorders – a report from the Adult Dental Health Survey 2009*, 2011.
22. Nuttall N, Tsakos G, Lader D, et al. *Outcome and impact – a report from the Adult Dental Health Survey 2009*: NHS Information Centre, 2011.
23. Steele J, Shen J, Tsakos G, et al. The Interplay between Socioeconomic Inequalities and Clinical Oral Health. *Journal of Dental Research* 2015;**94**(1):19-26.
24. Townsend N, Williams J, Bhatnagar P, et al. *Cardiovascular disease statistics 2014 edition*. London: British Heart Foundation, 2014.
25. Griffin SO, Jones JA, Brunson D, et al. Burden of oral disease among older adults and implications for public health priorities. *Am J Public Health* 2012;**102**(3):411-8.
26. Thomson WM, Ma S. An ageing population poses dental challenges. *Singapore Dental Journal* 2014;**35**(0):3-8.
27. Pretty IA, Ellwood RP, Lo ECM, et al. The Seattle Care Pathway for securing oral health in older patients. *Gerodontology* 2014;**31**:77-87.

Table 1 Number of teeth and periodontal disease in a population based study of 1660 older British men with dental examination aged 71-92 years in 2010-2012 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups		Social class		Region			
		71-79 years (n=1107, 67%)	80-92 years (n=553, 33%)	Non-manual (n=861, 53%)	Manual (n=751, 47%)	South of England (n=589, 35%)	Wales/ Midlands (n=264, 16%)	North of England (n=626, 38%)	Scotland (n=181, 11%)
Number of teeth in 1660 men									
No teeth	338 (20%)	183 (17%)	155 (28%)	123 (14%)	205 (27%)	82 (14%)	61 (23%)	137 (22%)	58 (32%)
1-7 teeth	123 (7%)	70 (6%)	53 (10%)	51 (6%)	70 (9%)	46 (8%)	19 (7%)	40 (6%)	18 (10%)
>7-14 teeth	265 (16%)	168 (15%)	97 (18%)	121 (14%)	134 (18%)	94 (16%)	43 (16%)	108 (17%)	20 (11%)
15-20	340 (20%)	233 (21%)	107 (19%)	185 (21%)	148 (20%)	119 (20%)	64 (24%)	116 (19%)	41 (23%)
≥21 teeth	594 (36%)	453 (41%)	141 (26%)	381 (44%)	194 (26%)	248 (42%)	77 (29%)	225 (36%)	44 (24%)
P value		<0.0001		<0.0001		<0.0001			
Periodontal disease in 1246 dentate men									
	n (%)	Age groups		Social class		Region			
		71-79 years (n=880, 71%)	80-92 years (n=366, 29%)	Non-manual (n=696, 57%)	Manual (n=519, 43%)	South of England (n=481, 39%)	Wales/ Midlands (n=192, 15%)	North of England (n=460, 37%)	Scotland (n=113, 9%)
Periodontal disease based on % sites with loss of attachment >5.5 mm									
0%	710 (57%)	520 (59%)	190 (52%)	401 (57%)	290 (56%)	262 (54%)	90 (47%)	293 (64%)	65 (58%)
1-20%	233 (19%)	167 (19%)	66 (18%)	146 (21%)	82 (16%)	91 (19%)	42 (22%)	83 (18%)	17 (15%)
>20%	303 (24%)	193 (22%)	110 (30%)	149 (21%)	147 (28%)	128 (27%)	60 (31%)	84 (18%)	31 (27%)
P value	-	0.008		0.006		0.001			
Periodontal pocket depth - % sites >3.5mm pocket depth									
0%	697 (56%)	505 (57%)	192 (53%)	391 (56%)	285 (55%)	280 (58%)	71 (37%)	273 (59%)	73 (65%)
1-20%	183 (15%)	132 (15%)	51 (14%)	114 (16%)	66 (13%)	67 (14%)	37 (19%)	69 (15%)	10 (9%)
>20%	365 (29%)	243 (28%)	122 (33%)	191 (27%)	167 (32%)	134 (28%)	84 (44%)	118 (26%)	29 (26%)
P value		0.12		0.08		<0.0001			
Gingival bleeding									
No gingival bleeding	1040 (84%)	740 (85%)	300 (82%)	578 (83%)	116 (17%)	402 (84%)	157 (82%)	386 (85%)	95 (84%)
Presence of gingival bleeding	198 (16%)	134 (15%)	64 (18%)	437 (85%)	76 (15%)	77 (16%)	34 (18%)	69 (15%)	18 (16%)
P value		0.32		0.37		0.87			

Table 2 Self-reported oral health in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups		Social class		Region			
		71-79 years (n=1373, 64%)	80-92 years (n=774, 36%)	Non-manual (n=1081, 52%)	Manual (n=1003, 48%)	South of England (n=736, 34%)	Wales/ Midlands (n=327, 15%)	North of England (n=843, 39%)	Scotland (n=241, 11%)
Self-rated oral health									
Excellent	271 (13%)	177 (13%)	94 (13%)	155 (15%)	103 (11%)	88 (12%)	43 (14%)	98 (12%)	42 (18%)
Good	1049 (51%)	707 (54%)	342 (48%)	561 (54%)	455 (49%)	366 (52%)	160 (52%)	412 (52%)	111 (48%)
Fair	587 (29%)	364 (28%)	223 (31%)	272 (26%)	303 (32%)	208 (29%)	81 (26%)	237 (30%)	61 (27%)
Poor	132 (6%)	71 (5%)	61 (8%)	56 (5%)	72 (8%)	48 (7%)	24 (8%)	45 (6%)	15 (7%)
P value		0.007		0.0003		0.43			
Natural teeth and dentures									
Only natural teeth	797 (38%)	562 (42%)	235 (31%)	467 (44%)	313 (32%)	292 (40%)	109 (34%)	318 (39%)	78 (33%)
Both natural teeth and dentures	882 (42%)	565 (42%)	317 (42%)	462 (44%)	390 (40%)	336 (47%)	133 (42%)	326 (39%)	87 (37%)
No natural teeth, and wear dentures	407 (19%)	210 (16%)	197 (26%)	128 (12%)	265 (27%)	92 (13%)	71 (22%)	175 (21%)	69 (29%)
Neither natural teeth nor dentures	14 (1%)	7 (1%)	7 (1%)	3 (.28%)	10 (1%)	2 (.28%)	3 (1%)	7 (1%)	2 (1%)
P value		<0.0001		<0.0001		<0.0001			

Table 3: Prevalence of self-reported dental problems in a population based study of 2147 British men aged 71-92 years in 2010-12 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups		Social class		Region			
		71-79 years	80-92 years	Non-manual	Manual	South of England	Wales/Midlands	North of England	Scotland
Dental problems									
Toothache, sensitivity, decay	538 (25%)	359 (26%)	179 (23%)	290 (27%)	231 (23%)	200 (27%)	80 (24%)	201 (24%)	57 (24%)
Loose tooth, or gum problems	246 (11%)	171 (12%)	75 (10%)	132 (12%)	108 (11%)	95 (13%)	27 (8%)	103 (12%)	21 (9%)
Bad position of teeth	64 (3%)	43 (3%)	21 (3%)	33 (3%)	28 (3%)	23 (3%)	10 (3%)	24 (3%)	7 (3%)
Ill-fitting denture or fractured tooth	277 (13%)	166 (12%)	111 (14%)	153 (14%)	112 (11%)	100 (14%)	38 (12%)	102 (12%)	37 (15%)
One or more of the above problems	908 (42%)	591 (43%)	317 (41%)	486 (45%)	392 (39%)	338 (46%)	133 (41%)	340 (40%)	97 (40%)
Impact on daily life due to dental problems									
Difficulty eating food	231 (11%)	122 (9%)	109 (14%)	104 (10%)	118 (12%)	86 (12%)	31 (9%)	81 (10%)	33 (14%)
Difficulty speaking	67 (3%)	32 (2%)	35 (5%)	27 (3%)	38 (4%)	23 (3%)	10 (3%)	31 (4%)	3 (1%)
Difficulty going out (for example, to shop or visit someone)	29 (1%)	17 (1%)	12 (2%)	9 (1%)	18 (2%)	7 (1%)	6 (2%)	14 (2%)	2 (1%)
Difficulty relaxing (including sleeping)	31 (1%)	19 (1%)	12 (2%)	11 (1%)	20 (2%)	9 (1%)	4 (1%)	15 (2%)	3 (1%)
Problems with smiling, laughing without embarrassment	83 (4%)	49 (4%)	34 (4%)	40 (4%)	39 (4%)	25 (3%)	17 (5%)	32 (4%)	9 (4%)
Emotional problems (example, becoming more easily upset than usual)	26 (1%)	13 (1%)	13 (2%)	10 (1%)	16 (2%)	7 (1%)	5 (2%)	12 (1%)	2 (1%)
Problems enjoying the company of others (example, family, friends)	31 (1%)	17 (1%)	14 (2%)	14 (1%)	15 (2%)	10 (1%)	6 (2%)	12 (1%)	3 (1%)
One or more of the above problems	304 (14%)	169 (12%)	135 (17%)	140 (13%)	154 (15%)	104 (14%)	43 (13%)	112 (13%)	45 (19%)

Table 4 Xerostomia (dry mouth) inventory in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study

	Never n (%)	Hardly ever n (%)	Occasionally n (%)	Fairly often n (%)	Very often n (%)
My mouth feels dry	963 (45)	449 (21)	516 (24)	149 (7)	70 (3)
I have difficulty in eating dry foods	1676 (78)	261 (12)	149 (7)	44 (2)	17 (1)
I get up at night to drink	1318 (61)	276 (13)	378 (18)	116 (5)	59 (3)
My mouth feels dry when eating a meal	1736 (81)	263 (12)	112 (5)	26 (1)	10 (0.50)
I sip liquids to aid in swallowing food	1687 (79)	192 (9)	187 (9)	55 (3)	26 (1)
I suck sweets or cough lollies to relieve dry mouth	1689 (79)	176 (8)	224 (10)	41 (2)	17 (1)
I have difficulties swallowing certain foods	1798 (84)	175 (8)	123 (6)	34 (2)	17 (1)
The skin of my face feels dry	1747 (81)	169 (8)	141 (7)	60 (3)	30 (1)
My eyes feel dry	1585 (74)	172 (8)	260 (12)	86 (4)	44 (2)
My lips feel dry	1480 (70)	241 (11)	321 (15)	81 (4)	24 (1)
The inside of my nose feels dry	1535 (72)	239 (11)	278 (13)	71 (3)	24 (1)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Checklist for the manuscript	Page number
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Yes	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Yes	2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Yes	3
Objectives	3	State specific objectives, including any prespecified hypotheses	Yes	3
Methods				
Study design	4	Present key elements of study design early in the paper	Yes	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Yes	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Yes	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Yes	4, 5, 6
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Yes	4, 5
Bias	9	Describe any efforts to address potential sources of bias	Yes	4, 5
Study size	10	Explain how the study size was arrived at	Yes	4, 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Yes	5, 6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Yes	5, 6
		(b) Describe any methods used to examine subgroups and	Yes	5, 6

1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			

Continued on next page

For peer review only

Results		Checklist for the manuscript	Page number
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Yes 6
		(b) Give reasons for non-participation at each stage	Yes 5, 6
		(c) Consider use of a flow diagram	Numbers given in text. 5, 6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Yes 6
		(b) Indicate number of participants with missing data for each variable of interest	Yes Tables 1 to 4
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Yes Tables 1 to 4
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A N/A
		(b) Report category boundaries when continuous variables were categorized	N/A N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Yes 6, 7
Discussion			
Key results	18	Summarise key results with reference to study objectives	Yes 8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Yes 8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Yes 9
Generalisability	21	Discuss the generalisability (external validity) of the study results	Yes 8, 9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Yes 11

1
2
3 *Give information separately for cases and controls in case-control studies and, if applicable, for exposed and
4 unexposed groups in cohort and cross-sectional studies.
5
6

7 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and
8 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely
9 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at
10 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is
11 available at www.strobe-statement.org.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

BMJ Open

The Burden of Poor Oral Health in Older Age: Findings from a Population-based Study of Older British Men

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2015-009476.R2
Article Type:	Research
Date Submitted by the Author:	24-Nov-2015
Complete List of Authors:	Ramsay, Sheena; UCL, Primary Care & Population Health Whincup, Peter; St Georges, University of London, Population Health Research Institute Watt, Richard; UCL, Epidemiology and Public Health Tsakos, Georgios; UCL, Epidemiology and Public Health Papacosta, Olia; UCL, Department of Primary Care and Population Health Lennon, Lucy; UCL, Department of Primary Care and Population Health Wannamethee, Goya; UCL, Department of Primary Care and Population Health
Primary Subject Heading:	Dentistry and oral medicine
Secondary Subject Heading:	Epidemiology, Public health, Geriatric medicine
Keywords:	EPIDEMIOLOGY, ORAL MEDICINE, PUBLIC HEALTH, GERIATRIC MEDICINE

SCHOLARONE™
Manuscripts

1
2 **The Burden of Poor Oral Health in Older Age: Findings from a Population-based Study of Older**
3 **British Men**
4

5
6
7 SE Ramsay,¹ PH Whincup,² RG Watt,³ G Tsakos,³ AO Papacosta,¹ LT Lennon,¹ SG Wannamethee¹

8
9 ¹Department of Primary Care & Population Health, UCL, London, UK

10 ²Population Health Research Institute, St George's University of London, London, UK

11 ³Department of Epidemiology & Public Health, UCL, London, UK
12
13

14
15 Corresponding author: SE Ramsay, s.ramsay@ucl.ac.uk, Department of Primary Care & Population Health,
16 UCL Medical School, Royal Free Campus, Rowland Hill Street, London NW3 2PF
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Abstract

Objectives: Evidence of the extent of poor oral health in the older UK adult population is limited. We describe the prevalence of oral health conditions, using objective clinical and subjective measures, in a population-based study of older men.

Design: Cross-sectional study

Setting and participants: A representative sample of men aged 71-92 years in 2010-12 from the British Regional Heart Study, initially recruited in 1978-80 from general practices across Britain. Physical examination among 1660 men included the number of teeth, and periodontal disease in index teeth in each sextant (loss of attachment, periodontal pocket, gingival bleeding). Postal questionnaires (completed by 2147 men including all participants who were clinically examined) included self-rated oral health, oral impacts on daily life and current perception of dry mouth experience.

Results: Among 1660 men clinically examined, 338 (20%) were edentulous and a further 728 (43%) had <21 teeth. For periodontal disease, 233 (19%) had loss of attachment (>5.5mm) affecting 1-20% of sites while 303 (24%) had >20% sites affected. The prevalence of gingival bleeding was 16%. Among 2147 men who returned postal questionnaires, 35% reported fair/poor oral health; 11% reported difficulty eating due to oral health problems. 31% reported 1-2 symptoms of dry mouth and 20% reported 3-5 symptoms of dry mouth. The prevalence of edentulism, loss of attachment, or fair/poor self-rated oral health was greater in those from manual social class.

Conclusions: These findings highlight the high burden of poor oral health in older British men. This was reflected in both the objective clinical and subjective measures of oral health conditions. The determinants of these oral health problems in older populations merit further research to reduce the burden and consequences of poor oral health in older people.

Strengths and limitations of this study

- This study provides novel information on the burden of oral health in a community-dwelling older British population.
- Study strengths are a socially and geographically representative sample of older British men, and the use of a range of subjective and objective clinical oral health measures.
- Limitations include limited generalisability of findings to older women and non-white ethnic groups, and lack of data on dental caries.

Introduction

Countries such as the UK are experiencing a dramatic demographic shift, with a growing population of older people. The number of people aged ≥ 65 years and ≥ 85 years in England and Wales is projected to increase by 25% and 50% respectively by 2033.¹ These patterns of an ageing population in the UK and other countries have important public health implications,² as increasing age is strongly associated with chronic disease and disability.¹ Therefore, there is a greater imperative to prevent and manage chronic diseases and maintain optimal functioning in older people.² Despite increasing research into healthy ageing and improving independence in older age, there is relatively less emphasis on oral health problems, which have a significant impact on quality of life, nutritional intake, and well-being in older age.³ The Global Burden of Disease 2010 Study showed that oral health problems accounted for 15 million disability-adjusted life years, implying an average health loss of 224 years per 100,000 population;⁴ furthermore, due to population ageing, the burden of oral health problems increased from 1990 to 2010.⁴ This burden particularly from periodontal (gum) disease and tooth loss, increases with age.⁴ A review of the epidemiology of oral health conditions in older people highlighted the burden of conditions including tooth loss and dry mouth in older people.⁵ Although edentulism (complete loss of natural teeth) has declined in recent decades in several countries,⁵ a substantial number of older people are still edentulous (2.7 million in the UK in 2009),⁶ and partial tooth loss remains an important problem affecting eating and quality of life of older people.

In order to effectively address the issue of poor oral health in older people, it is important to understand the extent of the problem. There are few population-based epidemiological studies of older people in the UK that describe the burden of oral health problems and needs in later life. Most evidence is from studies or surveys that are not specific to older people, such as the Adult Dental Health Survey,⁸ or which have limited information on oral health, such as self-report of having natural teeth, or self-rated oral health as in the English Longitudinal Study of Ageing.^{7,8} The National Diet and Nutrition Survey in 1994-95 was the last study specifically of older people in Britain (aged >65 years) that included an oral health examination.⁹ An improved understanding of the burden of oral health problems in the UK is urgently needed in people aged over 70 years in order to understand the health needs of this growing population. This aim of this study was to describe the burden of poor oral health in a representative population-based sample of community-dwelling British men aged 71-92 years. We describe a range of oral health conditions based on both objective clinical measures, such as number of teeth, periodontal disease, oral inflammation, and also subjective measures such as self-rated oral health, impact of oral health on daily activities and dry mouth – these assessments capture a range of dental diseases and oral health conditions that are particularly important in older age.

Methods

The British Regional Heart Study (BRHS) is a prospective study of a socially and geographically representative sample of 7735 men, aged 40-59 years from one general practice in each of 24 towns representing all major British regions, were initially examined in 1978-1980.¹⁰ In 2010-2012 all surviving men (n=3137, 41%) aged 71-92 years were invited to attend a 30-year re-examination.¹¹ Ethical approval was provided by all relevant local research ethics committees. All participating men provided written informed consent for the investigations, which were carried out in accordance with the Declaration of Helsinki. Participants underwent a physical examination and completed a questionnaire (at the time of examination or sent by post if they did not attend the examination) providing information on their medical history and lifestyle factors. Occupational social class was based on the longest-held occupation recorded at study entry (aged 40-59 years) and comprised six social class groups - I (professionals, e.g. physicians, engineers), II (managerial, e.g. teachers, sales managers), III non-manual (semi-skilled non-manual, e.g. clerks, shop assistants), III manual (semi-skilled manual, e.g. bricklayers), IV (partly skilled, e.g. postmen) and V (unskilled, e.g. porters, general labourers). For the purposes of this study, social classes III-manual, IV and V were grouped as manual social class and those from the Armed Forces were not included (n=63).

The physical examination of participants in 2010-12, at age 71-92 years, included for the first time a brief oral health assessment. Dental measures included a count of the number of teeth, and three measures of periodontal disease – periodontal pocket depth (measures the distance between the gum tissue and its attachment to the tooth, loss of attachment (the distance between the point at which the gum is attached and the “neck” of the tooth where the gum is attached in a healthy tooth), and bleeding on probing (a marker of current inflammation of the gums). Periodontal disease measurements were made in six index teeth (three in the upper arch and three in the lower arch), one per mouth sextant of the mouth. First molars were measured in the four posterior sextants, and right central incisors in the two anterior sextants; where the first molar was missing, the following tooth was chosen in order of priority: second premolar, first premolar, second molar; if the central incisor was missing, the next mesial tooth available in that sextant was chosen. Loss of attachment and gingival bleeding were assessed at two sites (mesiobuccal and distobuccal) on each index tooth, and periodontal pocket depth was measured on the mesiobuccal site. A CPITN (Community Periodontal Index of Treatment Needs) probe was used, with a 0.5mm ball-ended tip with markings at 0 to 3.5mm, >3.5mm to 5.5mm, and >5.5mm. Examiners (research nurses) underwent extensive training and calibration including a pilot prior to the study and a calibration check during the study. Agreement was tested between each examiner and the training examiner (dental surgeon) for every reading for the three periodontal disease measures (loss of attachment, periodontal pocket depth, gingival bleeding). Examiner and trainer agreement ranged from 89% to 95% (closest agreement was for gingival bleeding), and the median Kappa index was 0.79. It was not possible to include other measures of dental disease (such as dental caries) in the dental examination because of time constraints on the physical

1 examination of participants; the dental examination was part of an extensive physical examination. Given
2 the advanced age of the participants (71-92 years), it was important to avoid participant burden and,
3 therefore, only a very brief dental examination was possible.
4
5
6
7

8 The questionnaire included the following self-reported oral health measures: presence of teeth or
9 dentures, self-rated oral health (excellent, good, fair, poor), experience of dental problems, oral impacts on
10 daily life, dry mouth and dental service use (frequency of visiting a dentist and time since last dental visit).
11 Participants were asked questions on common dental or oral health problems experienced in the past 6
12 months, including toothache or sensitivity, loose tooth or gum problems, bad position of teeth, fractured
13 tooth, loose or ill-fitting dentures, appearance of teeth. Oral health related quality of life (OHRQoL) was
14 assessed through the Oral Impact on Daily Performances (OIDP) measure.¹² Participants were asked
15 whether in the past 6 months any oral health problems caused any of the following: difficulty eating,
16 difficulty speaking, difficulty going out (for example to shop or visit someone), difficulty relaxing (including
17 sleeping), problems with smiling, laughing and showing teeth without embarrassment, emotional problems
18 such as becoming more easily upset than usual, problems enjoying the company of others (for example,
19 family, friends, neighbours). The Xerostomia Inventory (XI), a validated tool to assess dry mouth and its
20 severity, was also used in the questionnaire.¹³ The Xerostomia Inventory questions include asking whether
21 in the past 4 weeks the participants experienced the following symptoms: mouth feels dry, difficulty eating
22 dry foods, getting up at night to drink, mouth feels dry when eating a meal, sip liquids to aid swallowing
23 food, sucking sweets to relieve dry mouth, difficulties swallowing certain foods, skin of face feels dry, eyes
24 feel dry, lips feel dry, inside of nose feels dry. Responses to each question were never, hardly ever,
25 occasionally, fairly often, or very often.
26
27
28
29
30
31
32
33
34
35
36
37
38

39 Statistical analyses

40 Descriptive analyses were carried out to determine the prevalence of the different aspects of oral health
41 measures. The number of teeth was categorised into no teeth, 1-7, >7-14, 15-20 and >21 teeth.¹⁴
42 Periodontal disease based on loss of attachment was categorised based on the proportion of sites with
43 >5.5mm; this was calculated as the number of sites affected with a loss of attachment of >5.5mm as a
44 proportion of sites examined, and categorised as 0%, 1-20% and >20% sites affected. For periodontal
45 pockets, we calculated the number of sites with >3.5mm pocket depth as a proportion of sites examined,
46 in order to obtain the percentage of sites affected, which was further categorised into 0%, 1-20% and >20%
47 sites affected. This approach has been used in previous epidemiological studies.^{15 16} The number of teeth,
48 periodontal disease prevalence and self-reported oral health conditions were examined by to demographic
49 characteristics (age, social class and region of residence). Chi-squared tests were used to assess the
50 statistical significance of the observed differences. Age was categorised into two groups of 71-79 years and
51 80-92 years. Social class was used as two categories of non-manual and manual. Region was based on the
52
53
54
55
56
57
58
59
60

1 town of residence and categorised into groups of the four British regions represented in the study – South
2 of England, Wales/ Midlands, North of England and Scotland. Analyses were carried out using SAS version
3 9.3.
4
5
6
7

8 Results

9
10 A total of 1722 men (55% participation rate) attended the examination. Questionnaires were completed by
11 2147 men (68% response rate), including all those who attended the examination. Overall, the mean age of
12 the study population was 78 years, and 47% were from manual social class. Compared to the men to
13 responded to the questionnaire, the non-responders were older (mean age 80 years), and had a higher
14 proportion of manual social classes (61%). Based on data from a previous follow-up, the non-responders
15 also had higher levels of poor/fair self-rated health (27%) compared to responders (16%).
16
17
18
19
20

21 Of the 1722 men who were examined, 62 (3.6%) did not have information on objective clinical oral health;
22 therefore analyses based on these measures were restricted to 1660 men. Of those, 338 (20%) had no
23 natural teeth, 728 (43%) had 1-20 teeth and 594 (36%) had ≥ 21 teeth. Table 1 presents the prevalence of
24 edentulism, number of teeth, periodontal disease and gingival inflammation by age groups, social class and
25 region. Overall, 20% men were edentulous. The prevalence of edentulism was greater in the older age
26 group (80-92 years), and in those from manual social classes or from Scotland. Periodontal disease was
27 measured in 1246 dentate men (those with natural teeth). Overall, 43% of men (n=536) had loss of
28 attachment >5.5 mm; 24% (n=303) of men had $>20\%$ of sites affected by loss of attachment of 5.5mm and
29 19% had 1-20% sites so affected. Overall, 44% of men had a periodontal pocket >3.5 mm. The proportion of
30 men with 1-20% sites affected by periodontal pockets >3.5 mm was 15% (n=183) and that with $>20\%$ of
31 sites was 29% (n=365). A small proportion (3%) had periodontal pockets >5.5 mm. Gingival bleeding was
32 present in 198 men (16%). The older age group (80-92 years) and those from manual social classes had a
33 higher prevalence of attachment loss and deeper pocket depth ($>20\%$ sites affected) than those aged 71-79
34 years or those of non-manual social classes respectively. Those in the North of England had a lower
35 prevalence of attachment loss and periodontal pockets than those from other regions. The prevalence of
36 gingival bleeding did not differ by age, social class or region.
37
38
39
40
41
42
43
44
45
46
47
48

49 Table 2 presents the prevalence of self-rated oral health and presence of natural teeth and dentures in the
50 2147 men with questionnaire data. Overall, 35% reported fair/poor oral health, and 19% reported no
51 natural teeth and wearing dentures. The prevalence of reporting fair/poor self-rated oral health was higher
52 in older men and those from manual social classes, but did not vary by region. The self-report of having no
53 natural teeth and wearing dentures was higher in older subjects, manual social classes and those from
54 Scotland.
55
56
57
58
59
60

1 Table 3 presents data on other self-reported oral health problems. Overall, 25% reported having had
2 problems of toothache, sensitivity or tooth decay. The prevalence of one or more problems related to teeth
3 (including toothache, sensitivity, loose tooth, ill-fitting denture) was 42%. Reporting one or more such
4 problems was lower in manual social classes ($p=0.007$), but did not differ significantly by age ($p=0.35$) or by
5 region ($p=0.11$). The prevalence of oral impacts on daily performances (OIDP) was 11% for difficulty eating
6 food and 14% overall (at least one oral impact such as eating, speaking, and going out). The prevalence of
7 one or more oral impacts was higher in older men ($p=0.001$), but did not differ significantly by social class
8 ($p=0.01$) or region ($p=0.18$).
9

10 Table 4 presents the xerostomia inventory data. The mean xerostomia score was 16 (SD 6). Overall, 34%
11 reported that their mouth felt dry occasionally or more often. Some 31% reported 1-2 dry mouth
12 symptoms, 20% reported 3-5 symptoms and 8% reported >5 symptoms. Combining self-reported oral
13 health problems, oral impacts on daily activities, and dry mouth, the prevalence of one or more self-
14 reported dental problems was 73%.
15

16 Based on questions on use of dental services, 11% reported going to a dentist only when having a problem,
17 15% reported that they had never gone to a dentist.
18

19 Discussion

20 In this study, we aim to describe the burden of poor oral health in a socially representative sample of older
21 British men aged 71-92 years. Our findings show a high burden of oral health problems including tooth loss,
22 periodontal disease, poor self-rated oral health, oral impacts on eating, and dry mouth. Several of these
23 oral health conditions (including complete tooth loss, periodontal disease and poor self-rated oral health)
24 were greater in lower social classes and the older age groups. These findings emphasise the high oral
25 health-care needs in older populations and the need to understand ways to prevent and manage these
26 problems.
27

28 To our knowledge, this paper presents the most recent epidemiological population-based study of oral
29 health and function in a community-dwelling older British population aged over 70 years with objective
30 clinical and self-reported measures; there are few such data on older populations in the UK, apart from the
31 ten-yearly Adult Dental Health Surveys which is conducted across the adult population, and the National
32 Diet and Nutrition Survey from 1994-95. Other studies in older populations in the UK have limited self-
33 reported data on oral health.⁷ We present results from a cross-sectional study of a socially and
34 geographically representative cohort of older British men. However, survivor bias is inevitable in a cohort
35 sample of an ageing population; participants with higher rates of chronic diseases would have died. The
36 moderate response rate for the clinical examination (55%) is also likely to have excluded participants in
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1 worse health. As observed in previous examinations,¹⁷ non-responders were older than responders and
2 had higher proportions of manual social class and poor/fair self-rated overall health, which are also likely to
3 be associated with having worse oral health. Therefore, it is possible that our findings have under-
4 estimated the burden of oral health in the older population. Another limitation is that this study comprises
5 only white European men, and the findings cannot be generalized to women or other ethnic groups. The
6 Adult Dental Health survey reported better periodontal health in women than men.⁶ Nevertheless, we
7 believe the findings provide a valuable insight into the epidemiology and burden of poor oral health in
8 older British populations.
9

10 Reports from the 10-yearly Adult Dental Health Surveys (most recently in 2009) have shown that the
11 prevalence of edentulism (no natural teeth) in adults declined by 22% from 1978 to 6% in 2009.^{8, 18} The
12 proportion of adults with ≥ 21 teeth (widely used to define a minimum functional dentition), is reported to
13 have increased, from 73% in 1978 to 86% in 2009.¹⁸ These patterns have also been observed in countries
14 other than the UK.⁵ In the National Diet and Nutrition Survey of 1994-95, 45% of free-living adults aged >65
15 years were edentulous.¹⁹ Although retention of teeth has improved overall in adults, tooth loss (partial or
16 complete) increases dramatically with age and remains a significant problem in older age.¹⁸ The Adult
17 Dental Health Survey 2009 documented the marked increase in loss of teeth in older age groups;¹⁸ the
18 prevalence of edentulism was 30% in adults aged 75-84 years and 47% in those aged >85 years. In the
19 English Longitudinal Study of Ageing, 26% of men and women >60 years in 2002-2003 reported having no
20 natural teeth.²⁰ Our findings, based on men aged 71-92 years, showed a prevalence of being edentate of
21 20%, and that only 31% had ≥ 21 teeth.
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

37 We used three measures to assess periodontal disease – gingival bleeding (a marker of current
38 inflammation of the gums), periodontal pockets (a deeper pocket indicates active periodontal disease), and
39 loss of attachment (a marker of experience of periodontal disease).⁶ Our sample of older men had a high
40 prevalence of excess loss of attachment, a longer-term measure of damage to periodontal tissue, while
41 deep periodontal pockets and gingival inflammation (indicators of active periodontal disease) were less
42 prevalent. The Adult Dental Health Survey reported higher proportions of severe (76%) and moderate loss
43 of attachment (25%) than our study;²¹ this could be higher since it was based on the highest measure
44 recorded on any tooth, whereas our measure was based only on six index teeth. Apart from the Adult
45 Dental Health Survey, most studies on the prevalence of periodontal disease and oral disease in older
46 people are from non-UK populations. Variations in measurement of periodontal disease make it difficult for
47 comparisons between studies, with few national level data on periodontal disease;⁵ estimates of
48 periodontal disease prevalence in 65-74 year olds are reported to range from 4% in New Zealand to 40% in
49 Germany.⁵
50
51
52
53
54
55
56
57
58
59
60

1 Self-reported oral health problems in our study ranged from self-rated oral health to dry mouth symptoms.
2
3 We found that over a third of the participants reported fair or poor self-rated oral health. The most
4
5 prevalent oral health problems were toothache, sensitivity and ill-fitting dentures. Over 40% of men
6
7 reported one or more oral health problems. The most common oral impact was difficulty eating. In relation
8
9 to xerostomia, a third of participants reported that their mouth felt dry, and a third reported one or two
10
11 symptoms of dry mouth. Over 70% of our sample reported one or more of these problems combined
12
13 (problems with teeth or gums, oral impact on daily activities and dry mouth). Notably our findings also
14
15 show a very high prevalence (73%) of oral health problems occurring in combination, such as problems with
16
17 teeth/gums along with difficulty eating and dry mouth. The Adult Dental Health Survey also reported high
18
19 rates of self-reported oral health problems such as impact on eating, particularly in older age groups.²²

20 The prevalence of most oral health conditions (edentulism, lower number of teeth, severe periodontal
21
22 disease, and fair/poor self-rated oral health) was greater in manual (or lower socioeconomic groups) than
23
24 in non-manual social class groups in our study. Similar patterns have been reported in other British studies.⁷

25 ²³ Determinants of these socioeconomic differences in oral health in older populations need to be further
26
27 investigated. Regional differences were most markedly observed for edentulism, with the lowest rates in
28
29 the South of England and the highest in Scotland. This is in keeping with observations of other conditions
30
31 such as cardiovascular disease.²⁴

32 Implications and conclusions

33
34 This study highlights a substantial burden of oral health in the older population which has important
35
36 implications for public health policy, clinical practice, and research. Improving the health of an increasingly
37
38 ageing population needs to address the oral health problems in this population, particularly in those from
39
40 lower socioeconomic status groups. Treatment and management of oral health problems in older people is
41
42 further complicated by age-related changes in the mouth, the presence of co-morbidities and issues of
43
44 access to dental care.^{25 26} Care pathways for oral healthcare of older people need to adapt to the needs of
45
46 older people.²⁷ Ageing research also currently largely focuses on managing long-term conditions and
47
48 improving disability and frailty in older age; there is little emphasis on preventing oral health problems in
49
50 later life and its importance in improving healthy ageing. There remains a need to investigate determinants
51
52 (biological and social) that are important in improving oral health and function in later life. Population-
53
54 based studies are also needed to understand the contribution of oral health to overall health in later life
55
56 alongside other aspects of healthy ageing such as disability, frailty and chronic diseases.
57
58
59
60

1 Author contributions: SER, SGW, PHW, RGW, GT developed the original idea for the paper. SER wrote the
2 first draft. SER and AOP performed the analyses. SER, PHW, SGW, LTL, AOP, RGW, GT contributed to the
3 study design and collation of data. All authors contributed to interpretation of data and the final version of
4 the manuscript, and all are guarantors.
5
6
7

8
9 Funding: The British Regional Heart Study was supported by a British Heart Foundation Programme Grant
10 (RG/08/013/25942). SER is funded by a UK MRC Fellowship (G1002391). The views expressed in this paper
11 are those of the authors and not necessarily those of the funding bodies.
12
13

14 Competing interests: None.
15

16
17 Ethical approval: The British Regional Heart Study has local (from each of the districts in which the study
18 was based) and multicentre ethical committee approvals.
19

20 Data sharing: No additional data available.
21
22
23
24
25

26 References

- 27 1. Change SCOPsAD. *Ready for Ageing? Report*. London: The Stationery Office, 2013.
- 28 2. Beard JR, Bloom DE. Towards a comprehensive public health response to population ageing. *The Lancet*
29 2015;**385**(9968):658-61.
- 30 3. Petersen PE, Yamamoto T. Improving the oral health of older people: the approach of the WHO Global
31 Oral Health Programme. *Community Dent Oral Epidemiol* 2005;**33**:81-92.
- 32 4. Marcenes W, Kassebaum NJ, Bernabe E, et al. Global burden of oral conditions in 1990-2010: a
33 systematic analysis. *J Dent Res* 2013;**92**(7):592-7.
- 34 5. Thomson WM. Epidemiology of oral health conditions in older people. *Gerodontology* 2014;**31**:9-16.
- 35 6. White DA, Tsakos G, Pitts NB, et al. Adult Dental Health Survey 2009: common oral health conditions and
36 their impact on the population. *Br Dent J* 2012;**213**(11):567-72.
- 37 7. Tsakos G, Demakakos P, Breeze E, et al. Social Gradients in Oral Health in Older Adults: Findings From the
38 English Longitudinal Survey of Aging. *American Journal of Public Health* 2011;**101**(10):1892-99.
- 39 8. Steele JG, Treasure ET, O'Sullivan I, et al. Adult Dental Health Survey 2009: transformations in British oral
40 health 1968-2009. *Br Dent J* 2012;**213**(10):523-27.
- 41 9. Sheiham A, Steele JG, Marcenes W, et al. The impact of oral health on stated ability to eat certain foods;
42 Findings from the National Diet and Nutrition Survey of Older People in Great Britain. *Gerodontology*
43 1999;**16**(1):11-20.
- 44 10. Walker M, Whincup PH, Shaper AG. The British Regional Heart Study 1975-2004. *Int J Epidemiol*
45 2004;**33**:1185-92.
- 46 11. Lennon- Ramsay S, Papacosta O, Shaper AG, et al. Cohort Profile Update: The British Regional Heart
47 Study 1978-2014: 35 years follow-up of cardiovascular disease and ageing. *International Journal of*
48 *Epidemiology* 2015;**44**:826-26g.
- 49 12. Tsakos G, Marcenes W, Sheiham A. Evaluation of a modified version of the index of Oral Impacts On
50 Daily Performances (OIDP) in elderly populations in two European countries. *Gerodontology*
51 2001;**18**(2):121-30.
- 52 13. Thomson WM, Chalmers JM, Spencer AJ, et al. The Xerostomia Inventory: a multi-item approach to
53 measuring dry mouth. *Community Dent Health* 1999;**16**(1):12-7.
- 54 14. Eke PI, Page RC, Wei L, et al. Update of the Case Definitions for Population-Based Surveillance of
55 Periodontitis. *Journal of Periodontology* 2012;**83**(12):1449-54.
56
57
58
59
60

15. Carlos JP, Wolfe MD, Kingman A. The extent and severity index: a simple method for use in epidemiologic studies of periodontal disease. *J Clin Periodontol* 1986;**13**(5):500-5.
16. Weyant RJ, Newman AB, Kritchevsky SB, et al. Periodontal Disease and Weight Loss in Older Adults. *Journal of the American Geriatrics Society* 2004;**52**(4):547-53.
17. Thomas MC, Walker M, Lennon LT, et al. Non-attendance at re-examination 20 years after screening in the British Regional Heart Study. *Journal of Public Health* 2002;**24**(4):285-91.
18. Fuller E, Steele J, Watt R, et al. Oral health and function – a report from the Adult Dental Health Survey 2009. *Adult Dental Health Survey 2009*, 2011.
19. Sheiham A, Steele JG, Marcenes W, et al. The relationship between oral health status and Body Mass Index among older people: a national survey of older people in Great Britain. *Br Dent J* 2002;**192**:703-06.
20. Tsakos G, Watt RG, Rouxel PL, et al. Tooth Loss Associated with Physical and Cognitive Decline in Older Adults. *Journal of the American Geriatrics Society* 2015;**63**(1):91-99.
21. White D, Pitts N, Steele J, et al. *Disease and related disorders – a report from the Adult Dental Health Survey 2009*, 2011.
22. Nuttall N, Tsakos G, Lader D, et al. *Outcome and impact – a report from the Adult Dental Health Survey 2009*: NHS Information Centre, 2011.
23. Steele J, Shen J, Tsakos G, et al. The Interplay between Socioeconomic Inequalities and Clinical Oral Health. *Journal of Dental Research* 2015;**94**(1):19-26.
24. Townsend N, Williams J, Bhatnagar P, et al. *Cardiovascular disease statistics 2014 edition*. London: British Heart Foundation, 2014.
25. Griffin SO, Jones JA, Brunson D, et al. Burden of oral disease among older adults and implications for public health priorities. *Am J Public Health* 2012;**102**(3):411-8.
26. Thomson WM, Ma S. An ageing population poses dental challenges. *Singapore Dental Journal* 2014;**35**(0):3-8.
27. Pretty IA, Ellwood RP, Lo ECM, et al. The Seattle Care Pathway for securing oral health in older patients. *Gerodontology* 2014;**31**:77-87.

Table 1 Number of teeth and periodontal disease in a population based study of 1660 older British men with dental examination aged 71-92 years in 2010-2012 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups		Social class		Region				
		71-79 years (n=1107, 67%)	80-92 years (n=553, 33%)	Non-manual (n=861, 53%)	Manual (n=751, 47%)	South of England (n=589, 35%)	Wales/ Midlands (n=264, 16%)	North of England (n=626, 38%)	Scotland (n=181, 11%)	
Number of teeth in 1660 men										
No teeth	338 (20%)	183 (17%)	155 (28%)	123 (14%)	205 (27%)	82 (14%)	61 (23%)	137 (22%)	58 (32%)	
1-7 teeth	123 (7%)	70 (6%)	53 (10%)	51 (6%)	70 (9%)	46 (8%)	19 (7%)	40 (6%)	18 (10%)	
>7-14 teeth	265 (16%)	168 (15%)	97 (18%)	121 (14%)	134 (18%)	94 (16%)	43 (16%)	108 (17%)	20 (11%)	
15-20	340 (20%)	233 (21%)	107 (19%)	185 (21%)	148 (20%)	119 (20%)	64 (24%)	116 (19%)	41 (23%)	
≥21 teeth	594 (36%)	453 (41%)	141 (26%)	381 (44%)	194 (26%)	248 (42%)	77 (29%)	225 (36%)	44 (24%)	
P value		<0.0001		<0.0001		<0.0001				
Periodontal disease in 1246 dentate men										
	n (%)	Age groups		Social class		Region				
		71-79 years (n=880, 71%)	80-92 years (n=366, 29%)	Non-manual (n=696, 57%)	Manual (n=519, 43%)	South of England (n=481, 39%)	Wales/ Midlands (n=192, 15%)	North of England (n=460, 37%)	Scotland (n=113, 9%)	
Periodontal disease based on % sites with loss of attachment >5.5 mm										
0%	710 (57%)	520 (59%)	190 (52%)	401 (57%)	290 (56%)	262 (54%)	90 (47%)	293 (64%)	65 (58%)	
1-20%	233 (19%)	167 (19%)	66 (18%)	146 (21%)	82 (16%)	91 (19%)	42 (22%)	83 (18%)	17 (15%)	
>20%	303 (24%)	193 (22%)	110 (30%)	149 (21%)	147 (28%)	128 (27%)	60 (31%)	84 (18%)	31 (27%)	
P value	-	0.008		0.006		0.001				
Periodontal pocket depth - % sites >3.5mm pocket depth										
0%	697 (56%)	505 (57%)	192 (53%)	391 (56%)	285 (55%)	280 (58%)	71 (37%)	273 (59%)	73 (65%)	
1-20%	183 (15%)	132 (15%)	51 (14%)	114 (16%)	66 (13%)	67 (14%)	37 (19%)	69 (15%)	10 (9%)	
>20%	365 (29%)	243 (28%)	122 (33%)	191 (27%)	167 (32%)	134 (28%)	84 (44%)	118 (26%)	29 (26%)	
P value		0.12		0.08		<0.0001				
Gingival bleeding										
No gingival bleeding	1040 (84%)	740 (85%)	300 (82%)	578 (83%)	116 (17%)	402 (84%)	157 (82%)	386 (85%)	95 (84%)	
Presence of gingival bleeding	198 (16%)	134 (15%)	64 (18%)	437 (85%)	76 (15%)	77 (16%)	34 (18%)	69 (15%)	18 (16%)	
P value		0.32		0.37		0.87				

Table 2 Self-reported oral health in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups		Social class		Region				
		71-79 years (n=1373, 64%)	80-92 years (n=774, 36%)	Non-manual (n=1081, 52%)	Manual (n=1003, 48%)	South of England (n=736, 34%)	Wales/ Midlands (n=327, 15%)	North of England (n=843, 39%)	Scotland (n=241, 11%)	
Self-rated oral health										
Excellent	271 (13%)	177 (13%)	94 (13%)	155 (15%)	103 (11%)	88 (12%)	43 (14%)	98 (12%)	42 (18%)	
Good	1049 (51%)	707 (54%)	342 (48%)	561 (54%)	455 (49%)	366 (52%)	160 (52%)	412 (52%)	111 (48%)	
Fair	587 (29%)	364 (28%)	223 (31%)	272 (26%)	303 (32%)	208 (29%)	81 (26%)	237 (30%)	61 (27%)	
Poor	132 (6%)	71 (5%)	61 (8%)	56 (5%)	72 (8%)	48 (7%)	24 (8%)	45 (6%)	15 (7%)	
P value		0.007		0.0003		0.43				
Natural teeth and dentures										
Only natural teeth	797 (38%)	562 (42%)	235 (31%)	467 (44%)	313 (32%)	292 (40%)	109 (34%)	318 (39%)	78 (33%)	
Both natural teeth and dentures	882 (42%)	565 (42%)	317 (42%)	462 (44%)	390 (40%)	336 (47%)	133 (42%)	326 (39%)	87 (37%)	
No natural teeth, and wear dentures	407 (19%)	210 (16%)	197 (26%)	128 (12%)	265 (27%)	92 (13%)	71 (22%)	175 (21%)	69 (29%)	
Neither natural teeth nor dentures	14 (1%)	7 (1%)	7 (1%)	3 (.28%)	10 (1%)	2 (.28%)	3 (1%)	7 (1%)	2 (1%)	
P value		<0.0001		<0.0001		<0.0001				

Table 3: Prevalence of self-reported dental problems in a population based study of 2147 British men aged 71-92 years in 2010-12 in the British Regional Heart Study and sociodemographic factors

	n (%)	Age groups				Social class				Region						
		71-79 years		80-92 years		Non-manual		Manual		South of England		Wales/Midlands		North of England		Scotland
Dental problems																
Toothache, sensitivity, decay	538 (25%)	359 (26%)	179 (23%)	290 (27%)	231 (23%)	200 (27%)	80 (24%)	201 (24%)	57 (24%)							
Loose tooth, or gum problems	246 (11%)	171 (12%)	75 (10%)	132 (12%)	108 (11%)	95 (13%)	27 (8%)	103 (12%)	21 (9%)							
Bad position of teeth	64 (3%)	43 (3%)	21 (3%)	33 (3%)	28 (3%)	23 (3%)	10 (3%)	24 (3%)	7 (3%)							
Ill-fitting denture or fractured tooth	277 (13%)	166 (12%)	111 (14%)	153 (14%)	112 (11%)	100 (14%)	38 (12%)	102 (12%)	37 (15%)							
One or more of the above problems	908 (42%)	591 (43%)	317 (41%)	486 (45%)	392 (39%)	338 (46%)	133 (41%)	340 (40%)	97 (40%)							
Impact on daily life due to dental problems																
Difficulty eating food	231 (11%)	122 (9%)	109 (14%)	104 (10%)	118 (12%)	86 (12%)	31 (9%)	81 (10%)	33 (14%)							
Difficulty speaking	67 (3%)	32 (2%)	35 (5%)	27 (3%)	38 (4%)	23 (3%)	10 (3%)	31 (4%)	3 (1%)							
Difficulty going out (for example, to shop or visit someone)	29 (1%)	17 (1%)	12 (2%)	9 (1%)	18 (2%)	7 (1%)	6 (2%)	14 (2%)	2 (1%)							
Difficulty relaxing (including sleeping)	31 (1%)	19 (1%)	12 (2%)	11 (1%)	20 (2%)	9 (1%)	4 (1%)	15 (2%)	3 (1%)							
Problems with smiling, laughing without embarrassment	83 (4%)	49 (4%)	34 (4%)	40 (4%)	39 (4%)	25 (3%)	17 (5%)	32 (4%)	9 (4%)							
Emotional problems (example, becoming more easily upset than usual)	26 (1%)	13 (1%)	13 (2%)	10 (1%)	16 (2%)	7 (1%)	5 (2%)	12 (1%)	2 (1%)							
Problems enjoying the company of others (example, family, friends)	31 (1%)	17 (1%)	14 (2%)	14 (1%)	15 (2%)	10 (1%)	6 (2%)	12 (1%)	3 (1%)							
One or more of the above problems	304 (14%)	169 (12%)	135 (17%)	140 (13%)	154 (15%)	104 (14%)	43 (13%)	112 (13%)	45 (19%)							

Table 4 Xerostomia (dry mouth) inventory in a population based study of 2147 men aged 71-92 years in 2010-12 in the British Regional Heart Study

	Never n (%)	Hardly ever n (%)	Occasionally n (%)	Fairly often n (%)	Very often n (%)
My mouth feels dry	963 (45)	449 (21)	516 (24)	149 (7)	70 (3)
I have difficulty in eating dry foods	1676 (78)	261 (12)	149 (7)	44 (2)	17 (1)
I get up at night to drink	1318 (61)	276 (13)	378 (18)	116 (5)	59 (3)
My mouth feels dry when eating a meal	1736 (81)	263 (12)	112 (5)	26 (1)	10 (0.50)
I sip liquids to aid in swallowing food	1687 (79)	192 (9)	187 (9)	55 (3)	26 (1)
I suck sweets or cough lollies to relieve dry mouth	1689 (79)	176 (8)	224 (10)	41 (2)	17 (1)
I have difficulties swallowing certain foods	1798 (84)	175 (8)	123 (6)	34 (2)	17 (1)
The skin of my face feels dry	1747 (81)	169 (8)	141 (7)	60 (3)	30 (1)
My eyes feel dry	1585 (74)	172 (8)	260 (12)	86 (4)	44 (2)
My lips feel dry	1480 (70)	241 (11)	321 (15)	81 (4)	24 (1)
The inside of my nose feels dry	1535 (72)	239 (11)	278 (13)	71 (3)	24 (1)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Checklist for the manuscript	Page number
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	Yes	2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Yes	2
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Yes	3
Objectives	3	State specific objectives, including any prespecified hypotheses	Yes	3
Methods				
Study design	4	Present key elements of study design early in the paper	Yes	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Yes	4
Participants	6	(a) <i>Cohort study</i> —Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up <i>Case-control study</i> —Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls <i>Cross-sectional study</i> —Give the eligibility criteria, and the sources and methods of selection of participants	Yes	4
		(b) <i>Cohort study</i> —For matched studies, give matching criteria and number of exposed and unexposed <i>Case-control study</i> —For matched studies, give matching criteria and the number of controls per case	N/A	N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Yes	4, 5
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Yes	4, 5
Bias	9	Describe any efforts to address potential sources of bias	Yes	4, 5
Study size	10	Explain how the study size was arrived at	Yes	4, 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Yes	5, 6
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	Yes	5, 6
		(b) Describe any methods used to examine subgroups and	Yes	5, 6

1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			

Continued on next page

For peer review only

Results		Checklist for the manuscript	Page number
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Yes 6
		(b) Give reasons for non-participation at each stage	Yes 5, 6
		(c) Consider use of a flow diagram	Numbers given in text. 5, 6
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Yes 6
		(b) Indicate number of participants with missing data for each variable of interest	Yes Tables 1 to 4
		(c) <i>Cohort study</i> —Summarise follow-up time (eg, average and total amount)	N/A N/A
Outcome data	15*	<i>Cohort study</i> —Report numbers of outcome events or summary measures over time	N/A N/A
		<i>Case-control study</i> —Report numbers in each exposure category, or summary measures of exposure	N/A N/A
		<i>Cross-sectional study</i> —Report numbers of outcome events or summary measures	Yes Tables 1 to 4
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A N/A
		(b) Report category boundaries when continuous variables were categorized	N/A N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Yes 6, 7
Discussion			
Key results	18	Summarise key results with reference to study objectives	Yes 7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Yes 7, 8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Yes 8, 9
Generalisability	21	Discuss the generalisability (external validity) of the study results	Yes 8, 9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Yes 10

1
2
3 *Give information separately for cases and controls in case-control studies and, if applicable, for exposed and
4 unexposed groups in cohort and cross-sectional studies.
5
6

7 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and
8 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely
9 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at
10 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is
11 available at www.strobe-statement.org.
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only